MIDDLE ORDOVICIAN (WHITEROCKIAN-CHAZYAN) TRILOBITES FROM THE SUNBLOOD FORMATION, DISTRICT OF MACKENZIE

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By

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ABSTRACT

The Middle Ordovician Sunblood Formation in the South Nahanni River area, District of Mackenzie, comprises mainly limestones and dolostones of intertidal and shallow subtidal origin as indicated by the presence of desiccation polygons, fenestral fabric, and oncolites.

The study of well preserved, silicified trilobites from low diversity, *Bathyurus*-dominated, Nearshore Biofacies faunas of Whiterockian and Chazyan age collected in six stratigraphic sections through the Sunblood Formation permits the recognition of three new Whiterockian zones, and two previously established Chazyan zones. The *Bathyurus mackenziensis, Bathyurus sunbloodensis,* and *Bathyurus margareti* zones (Whiterockian), together with the *Bathyurus nevadensis* and *Bathyurus granulosus* zones (Chazyan) represent the Nearshore Biofacies components of a dual biostratigraphic scheme that considers both temporal and spatial distribution patterns, and are compositionally distinct from faunas in correlative strata around North America that represent other biofacies.

Twenty-six species belonging to eighteen genera are described and illustrated. *Ludvigsenella ellipsepyga* is established as a new bathyurine genus, in addition to four new species of *Bathyurus* : *Bathyurus mackenziensis, Bathyurus sunbloodensis, Bathyurus margareti* and *Bathyurus acanthopyga.* Other genera present are: *Basilicus, Isotelus, Illaenus, Bumastoides, Failleana, Phorocephala,*

Ceraurinella, Acanthoparypha, Xystocrania, Cydonocephalus, Ectenonotus, Pseudomera, Encrinuroides, Calyptaulax, Amphilichas and *Hemiarges.*

ACKNOWLEDGEMENTS

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Many people contributed their time and skills towards improving this thesis. At Brock University, Divino Mucciante developed many of the negatives, and Dan Redmond printed a considerable portion of the photographs. I thank Rick Cheel for reading a preliminary draft and making some constructive comments. Dave Rudkin, Joan Burke, and Janet Waddington at the Royal Ontario Museum were always very helpful and friendly.

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CHAPTER 1
INTRODUCTION

The southern Mackenzie Mountains expose a complete sequence of Middle Ordovician (Whiterockian, Chazyan, Blackriveran and Trentonian stages) carbonate strata. Mapping by the Geological Survey of Canada from the late 1950's through the mid 1960's (Douglas and Norris, 1960, 1961, 1963; Gabrielse et al., 1973) has facilitated lithostratigraphic work for this interval throughout the region (Ludvigsen, 1975a, b; Morrow and Cook, 1987), and Middle Ordovician rocks have been assigned in ascending order to the Sunblood, Esbataottine, and the lower Whittaker formations.

The trilobite zonation and biofacies of the Chazyan-Edenian portions of the Sunblood, Esbataottine, and Whittaker formations, as well as the paleogeography of the region have been studied by Ludvigsen (1975a, b, 1978, 1979), and Chatterton and Ludvigsen (1976). In addition, biofacies analysis of Chazyan - Blackriveran ostracodes, bryozoans and conodonts has been performed by Hayes (1980), and the systematics and biostratigraphy of Whiterockian through Edenian conodont and ostracode faunas have been analysed by Tipnis et al., (1978) and Copeland (1974, 1977, 1978) respectively. However, except for a cursory treatment of the "*Orthidiella - 'Goniotelina'* Fauna" by Ludvigsen (1975a, b, 1979), the trilobites of the Whiterockian Stage have not been studied.

The recently proposed dual biostratigraphy concept of Ludvigsen et al. (1986), which integrates the temporal (zones) and spatial (biofacies)

distribution of taxa, has implications for the trilobite biostratigraphy of the interval covered in this thesis. The Whiterockian *Bathyurus* - dominated collections from the District of Mackenzie are compositionally distinct from faunas of correlative mid- to outer shelf environments in Nevada and Utah (Ross, 1951, 1967, 1970, 1972; Hintze, 1953), Oklahoma (Shaw, 1974), and western Newfoundland (Whittington, 1963, 1965). Of these locations, a trilobite zonation has been established for Nevada and Utah (see Hintze, 1953), but these trilobite assemblage zones do not include species of *Bathyurus*, and they cannot be recognized in the study area. Therefore, a new set of trilobite zones must be established for the *Bathyurus* -dominated biofacies in the District of Mackenzie.

The purpose of this thesis is to describe and illustrate the trilobite faunas of Whiterockian and Chazyan age in the South Nahanni River area, to analyse the biofacies in which they occur, and to propose a new zonation scheme for the study interval that considers both the spatial and temporal distribution of trilobites.

The silicified trilobites studied were collected by Rolf Ludvigsen during the period from 1971 to 1976 from the Sunblood Formation at six different locations in the study area (Fig. 1). The study interval is confined to the fossiliferous Whiterockian and Chazyan portions of the sections (Fig. 2) exposed at these locations. Ludvigsen isolated the trilobites from the carbonate matrix but did no further work with the material and, except for a few specimens (Ludvigsen 1975a, pl. 1, figs. 10 - 13), none of the material has been illustrated or described. In addition to picked and unpicked silicified residues, Ludvigsen provided descriptions of

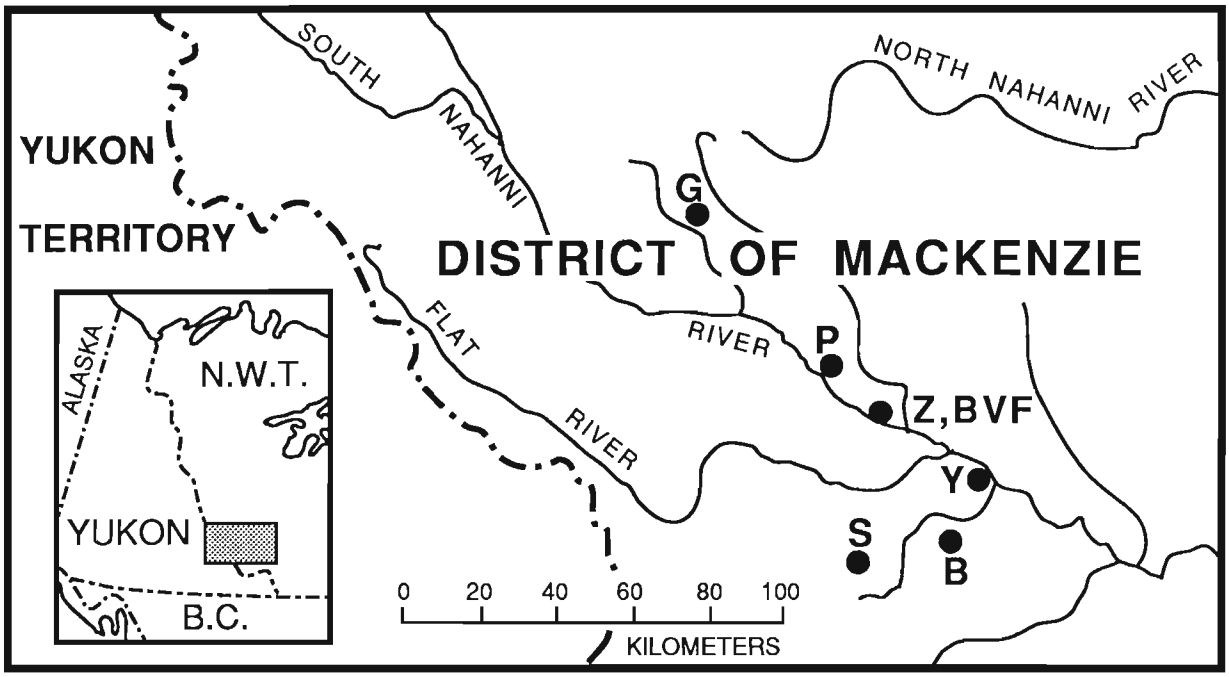

FIGURE 1a. Locality map of study area showing the six measured sections (modified from Ludvigsen, 1979).

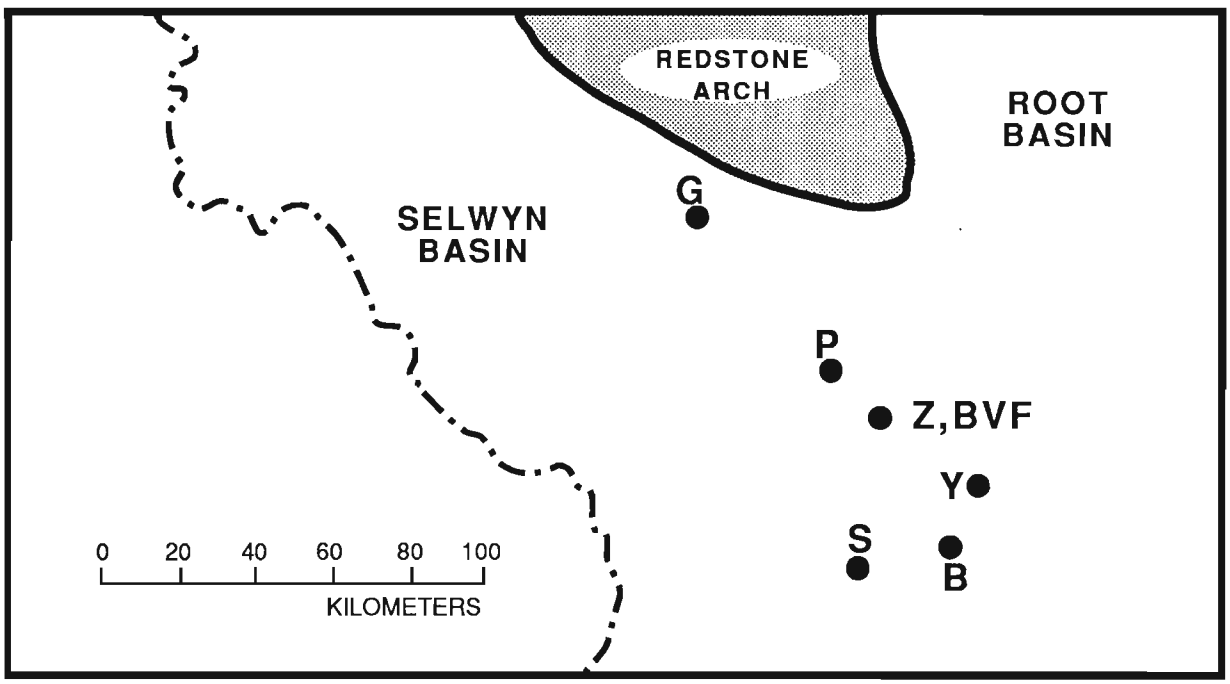

FIGURE 1b. Map showing location of the Redstone Arch, Root Basin, and Selwyn Basin (modified from Ludvigsen, 1975a).

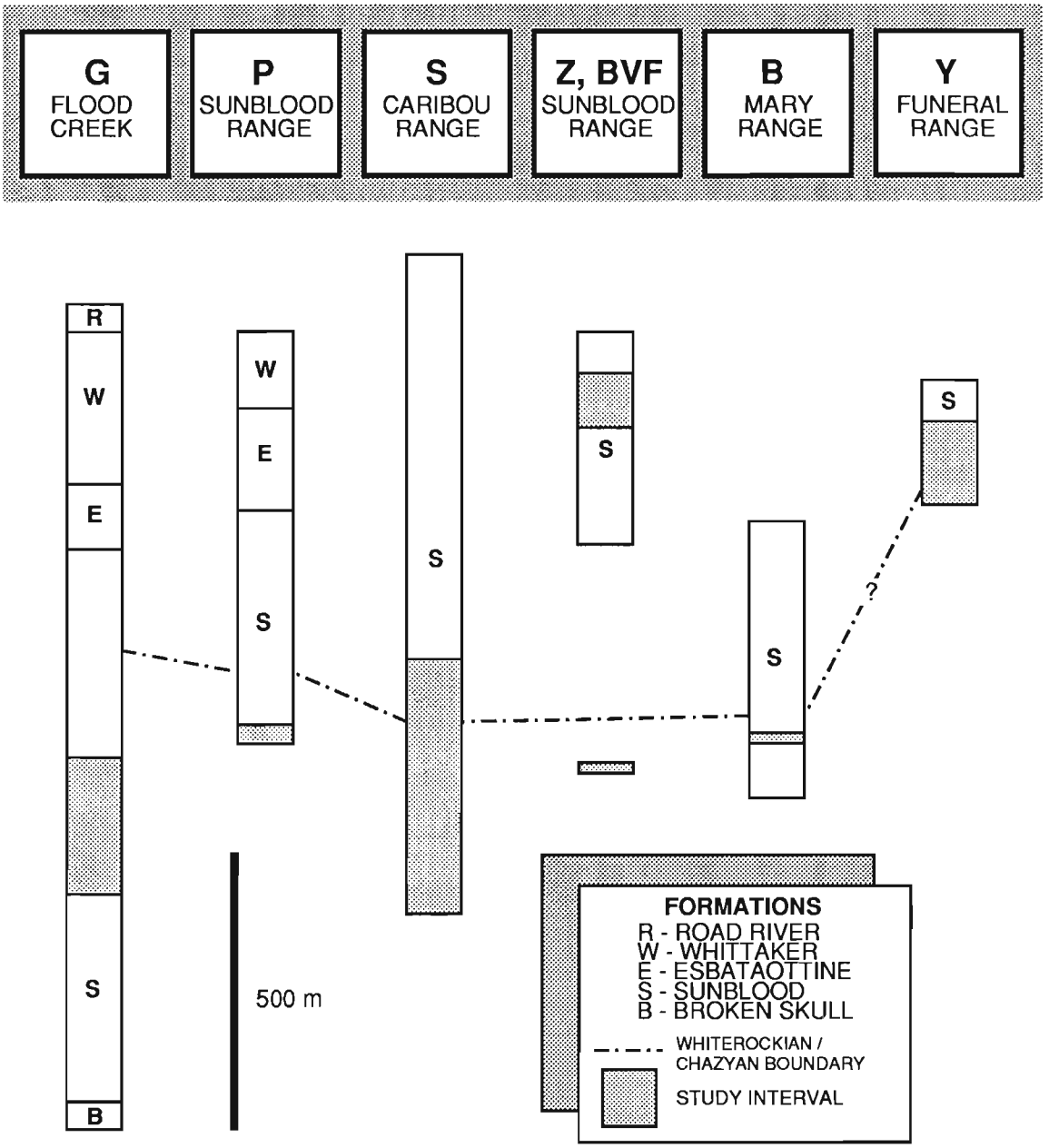

FIGURE 2. Correlation of measured sections, showing the study interval.

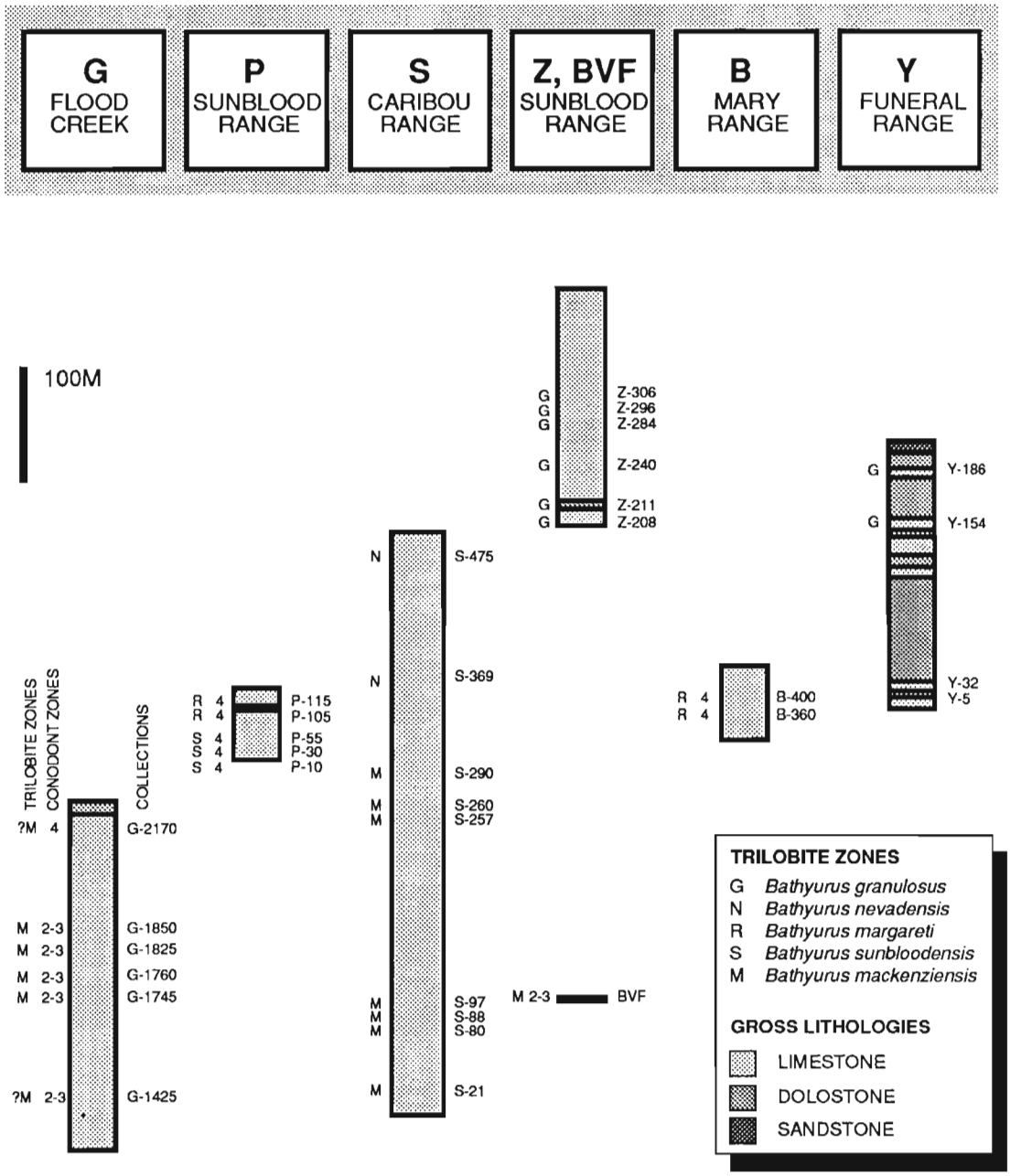

FIGURE 3.
Stratigraphic columns for the study intervals in each section, showing gross lithology and the occurences of collections, conodont zones (Tipnis et al., 1978) and trilobite zones.

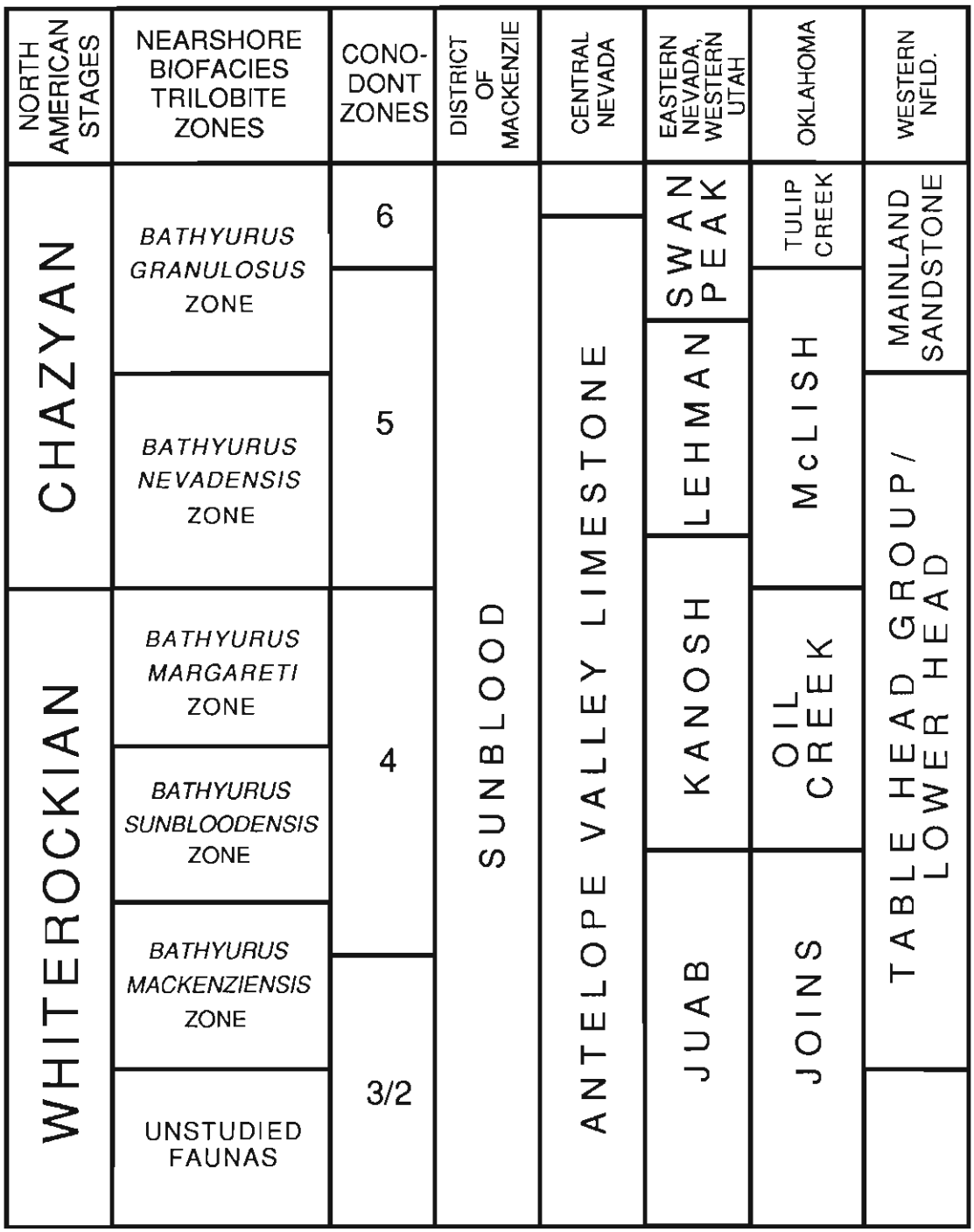

FIGURE 4. Correlation of the Sunblood Formation study interval with formations in Nevada, Utah, Oklahoma and Newfoundland.

measured stratigraphic sections, and some of his original field notes. The conodont and trilobite-based correlation of the six measured sections is provided in
Figs. 3 and 4.

STRATIGRAPHIC SETTING

Ludvigsen (1975a, 1979) discussed the sequence and distribution of the Ordovician formations and faunas in the study area. The overall basin setting, regional paleogeography, and some general features of the Sunblood Formation are briefly reviewed here.

In the South Nahanni River area of the District of Mackenzie, thick, well exposed sections of Ibexian Broken Skull Formation (Gabrielse*et al.* 1973), the Ibexian to Edenian Sunblood Formation (Kingston, 1951), and the Chazyan to Rocklandian Esbataottine Formation (Ludvigsen, 1975a) comprise the early record of platform carbonate sedimentation in the Root Basin and on the fringes of the Redstone Arch (Figs. 1b & 2). The Redstone Arch was a persistent positive feature during the Early and Middle Ordovician, and was likely emergent throughout the Whiterockian - Chazyan interval. During this time, the Root Basin to the east of the Redstone Arch was the site of carbonate sedimentation, while fine grained clastic facies were deposited in the Selwyn Basin to the west (Ludvigsen 1975a).

In the study area, the Sunblood Formation consists of red, orange, yellow, and pink weathering, medium to dark grey, finely crystalline to microcrystalline limestones, with minor amounts of buff coloured

dolostone. In sections G, P, and Y, the top of the Sunblood Formation is marked by a buff, brown, or orange weathering arenaceous unit. The formation attains a thickness of 1200 m in Section S, and in Section G it is just over 1000 m thick (Ludvigsen 1979). These are the only two measured sections in this thesis that sample the entire Sunblood Formation.

The Sunblood carbonates and siliciclastics were deposited in a relatively shallow subtidal to intertidal environment (Ludvigsen 1975a, Morrow and Cook 1987). Desiccation polygons occur in the upper portion of the formation at sections Y and Z, and ripple marks, fenestral fabric, and oncolites occur commonly in all sections. The trilobite *Bathyurus*, which is associated with shallow water, nearshore environments (Walker 1972; Ludvigsen 1978a), dominates the shelly faunas, with the addition of abundant cheirurid and pliomerid trilobites at some intervals in Section S. Leperditiid and leperditellid ostracodes are also common, while ramose bryozoans, gastropods, and orthid brachiopods occur rarely.

CHAPTER 2
BIOSTRATIGRAPHY

INTRODUCTION

The distribution of benthic marine organisms in ancient shelf and slope deposits is controlled by time and environment, and Middle Ordovician trilobites were spatially segregated on the continental shelf and slope into supraspecific associations termed biofacies. The concept of trilobite biofacies is not new. Earlier work on Cambrian trilobites (Lochman-Balk and Wilson, 1958) recognized biofacies realms concentrically surrounding the North American continent. More recent work on Cambrian (Palmer and Campbell 1976; Robison 1976; Taylor 1977; Ludvigsen and Westrop 1983, Ludvigsen et al. in press; Westrop 1986), Ordovician (Fortey, 1975; Ludvigsen, 1978b), and Silurian (Thomas, 1979; Mikulic and Watkins, 1981) faunas has also concluded that trilobites were segregated in to biofacies which reflect their original environmental distribution.

Traditionally, biostratigraphers have established zonations with little regard to the spatial distribution of trilobites in biofacies. However, some trilobites are highly facies specific, and zonations based on taxa of one biofacies may be of little use in contemporaneous strata containing taxa from other biofacies. Ludvigsen et al. (1986) convincingly

demonstrated the need for zonation schemes to be placed in the context of biofacies. Therefore, before a zonation scheme can be proposed for the study interval, an assessment of the trilobite biofacies represented in the collections must be made.

SPATIAL BIOSTRATIGRAPHY

Trilobite biofacies

Chazyan to Edenian trilobite biofacies in the study area have been fully documented by Ludvigsen (1975b, 1978b, 1979) and Chatterton and Ludvigsen (1976). In these studies, nearly 60 collections yielding about 13,000 individual trilobites formed the basis of Q and R-mode cluster analysis which was used to define biofacies. The Chazyan interval provided the greatest resolution for trilobite spatial distribution, and four biofacies (Fig. 5) extending from the paleo-shoreline to the slope were recognized by Ludvigsen (1978b). The low diversity (up to six species) nearshore Biofacies I is dominated by the genus *Bathyurus*, although small numbers of the genera *Calyptaulax*, *Ceraurinella, Isotelus*, *Amphilichas*, and *Nanillaenus* may be present. The higher diversity (up to nineteen species) open shelf Biofacies II and III contain abundant representatives of the latter five genera and many other genera, but *Bathyurus* is extremely rare. The upper slope Biofacies IV includes remopleuridids, proetids, raphiophorids, trinucleids, nileids and olenids and is quite different from

the three shelf biofacies. Overall, Biofacies I and IV are the most distinct, while Biofacies II and III share a number of taxa. Thus, for the purpose of integrating the spatial distribution of trilobites with a temporal zonation, Ludvigsen's scheme can be reduced to three biofacies: the Nearshore Biofacies (Biofacies I of Ludvigsen); the Midshelf Biofacies (Biofacies II and Biofacies III of Ludvigsen); and the Upper Slope Biofacies (Biofacies IV of Ludvigsen). An additional trilobite association, not recognized in the District of Mackenzie, is the illaenid and cheirurid biofacies (Fortey 1975). It was characteristic of reef environments in shelf interior and shelf margin sites, and has also been recorded from firm carbonate substrates in subtidal environments (Westrop 1983, Westrop and Ludvigsen 1984).

In this thesis, biofacies are defined on the basis of the relative abundances of genera and species diversity patterns in large collections (at least 100 individuals). Because of the relatively small number of collections, analysis was performed by visual comparison of pie diagrams.

The collections from the Whiterockian and Chazyan Sunblood Formation are dominated by species of *Bathyurus*, and the number of species in any collection never exceeds six (Fig. 6). This indicates that most of the collections in this study are representative of the Nearshore Biofacies (see also Walker 1972, and Ludvigsen, 1878a for other occurrences of *Bathyurus* dominated trilobite assemblages in nearshore strata outside of the study area). Sedimentological evidence for subaerial exposure, in the form of desiccation polygons, supports this conclusion. These mud cracks occur in sections Y and Z in the intervals between trilobite bearing beds, and indicate a relatively shallow

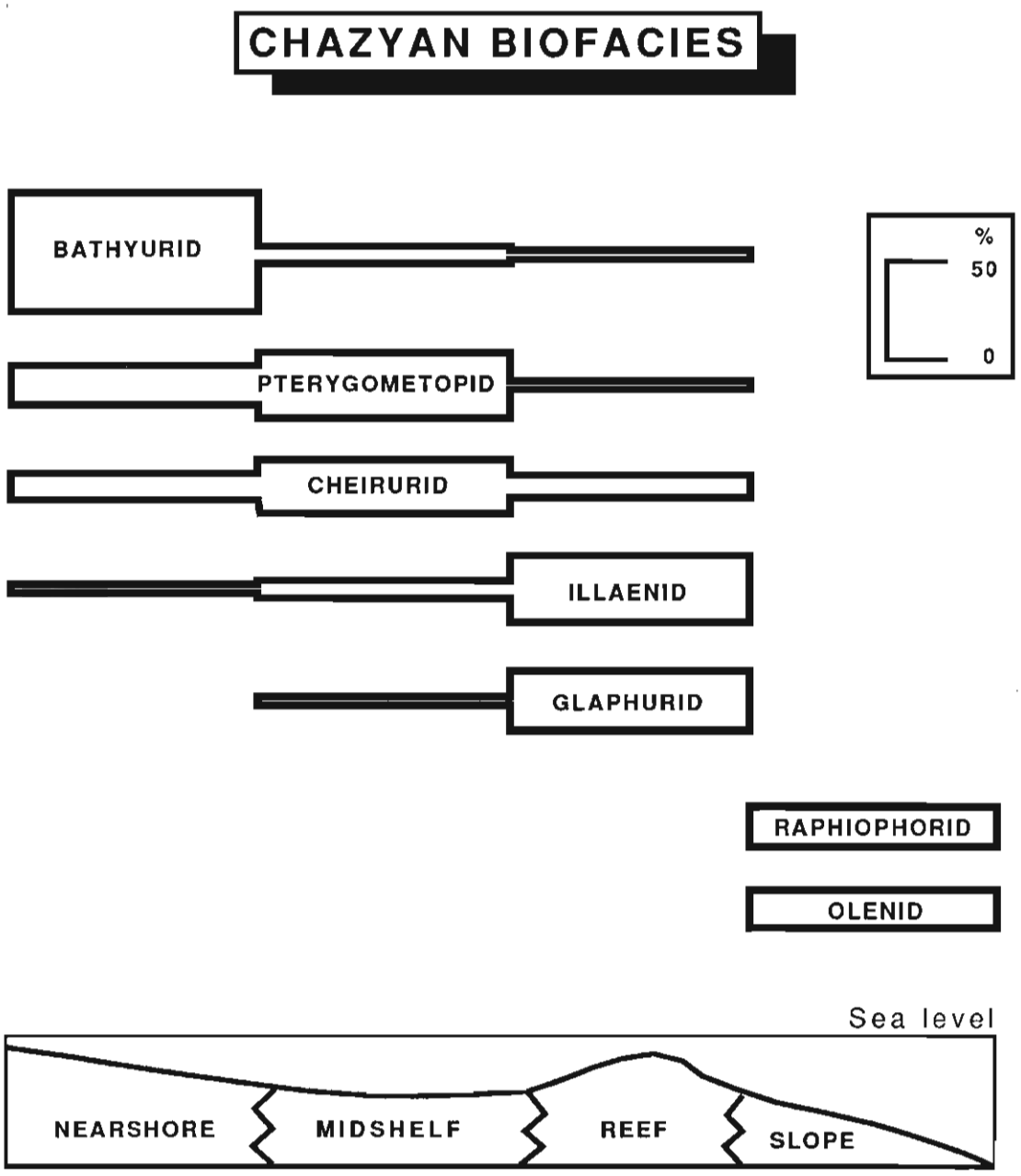

FIGURE 5. Distribution and compostition of Chazyan trilobite biofacies. Data is from (Ludvigsen 1978b) except for Reef Biofacies data from the Chazy Group of New York (Westrop 1983). Spindles represent relative abundances of trilobite families and subfamilies.

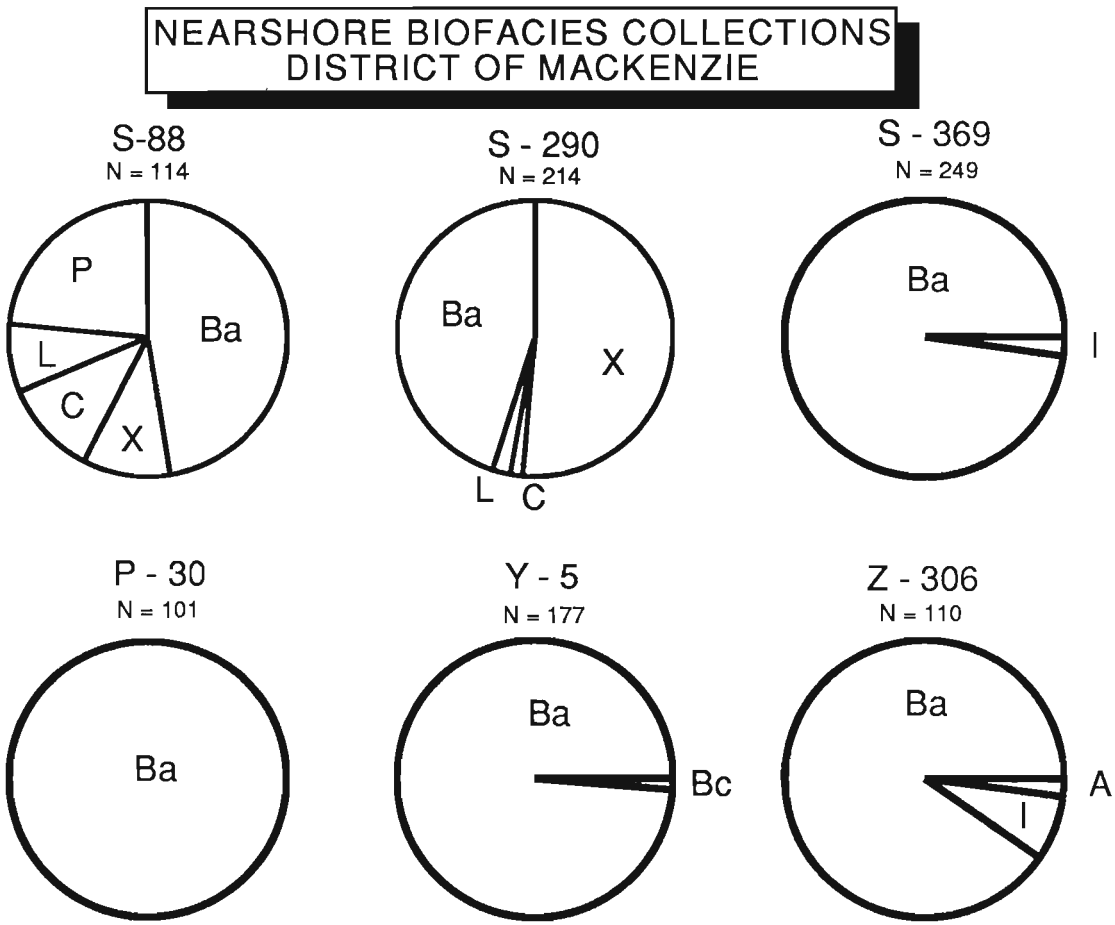

FIGURE 6. Generic composition of representative Nearshore Biofacies collections from the study interval. Ba=Bathyurus, P=Pseudomera, X=Xystocrania, C=Cydonocephalus, L=Ludvigsenella, I=Illaenus, A=Acanthoparypha, Bc=Basilicus.

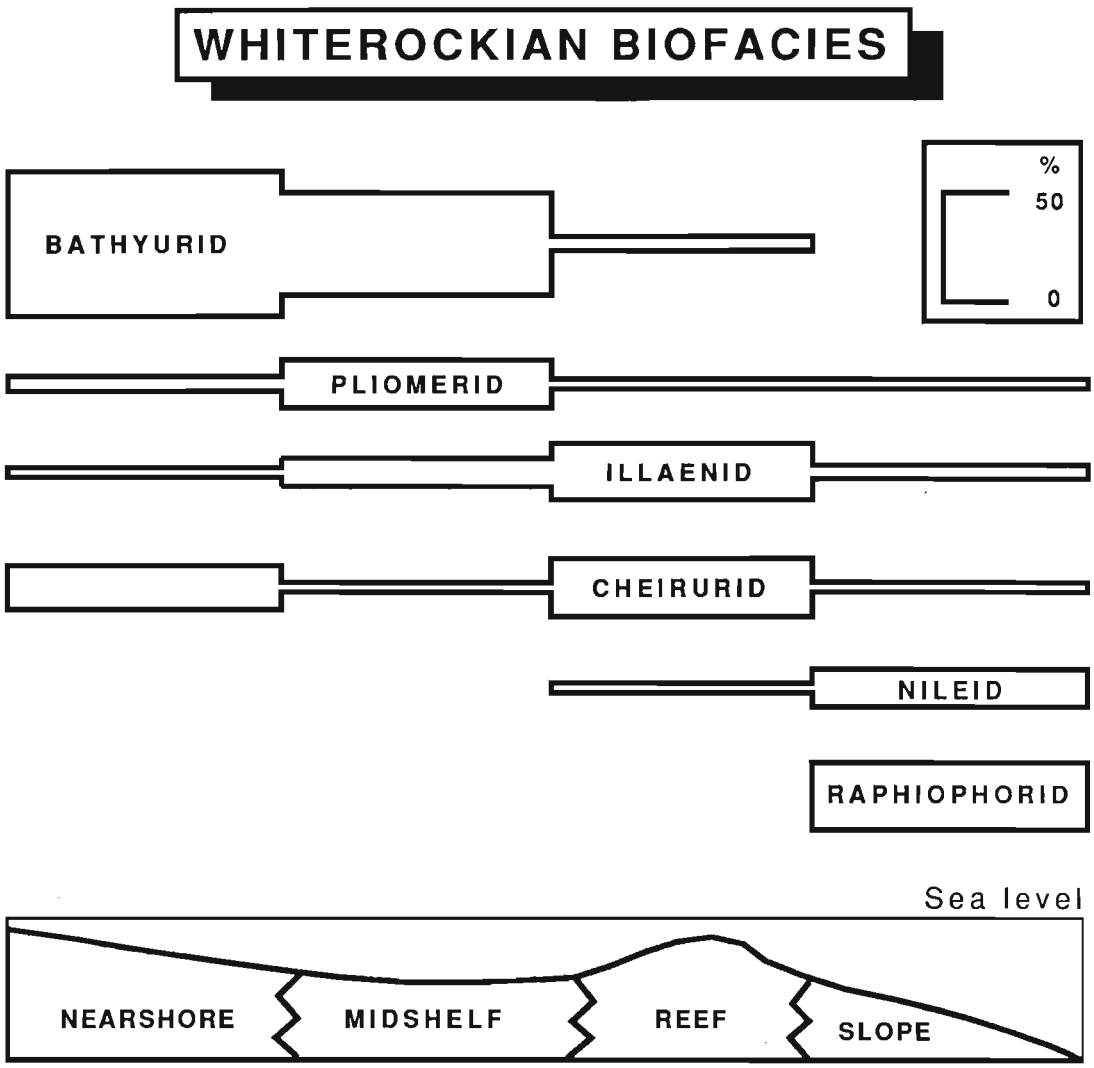

FIGURE 7. Distribution and composition of Whiterockian trilobite biofacies. The Nearshore Biofacies of the Sunblood Formation is compared with Midshelf Biofacies of the Oil Creek Formation (Shaw 1974), reef biofacies of the Lower Head Formation (Whittington 1963), and Slope Biofacies of the MiddleTable Head and Table Cove Formations (Whittington 1965). The spindles represent relative abundances of trilobite families. The genus Bathyurus is restricted to the Nearshore Biofacies.

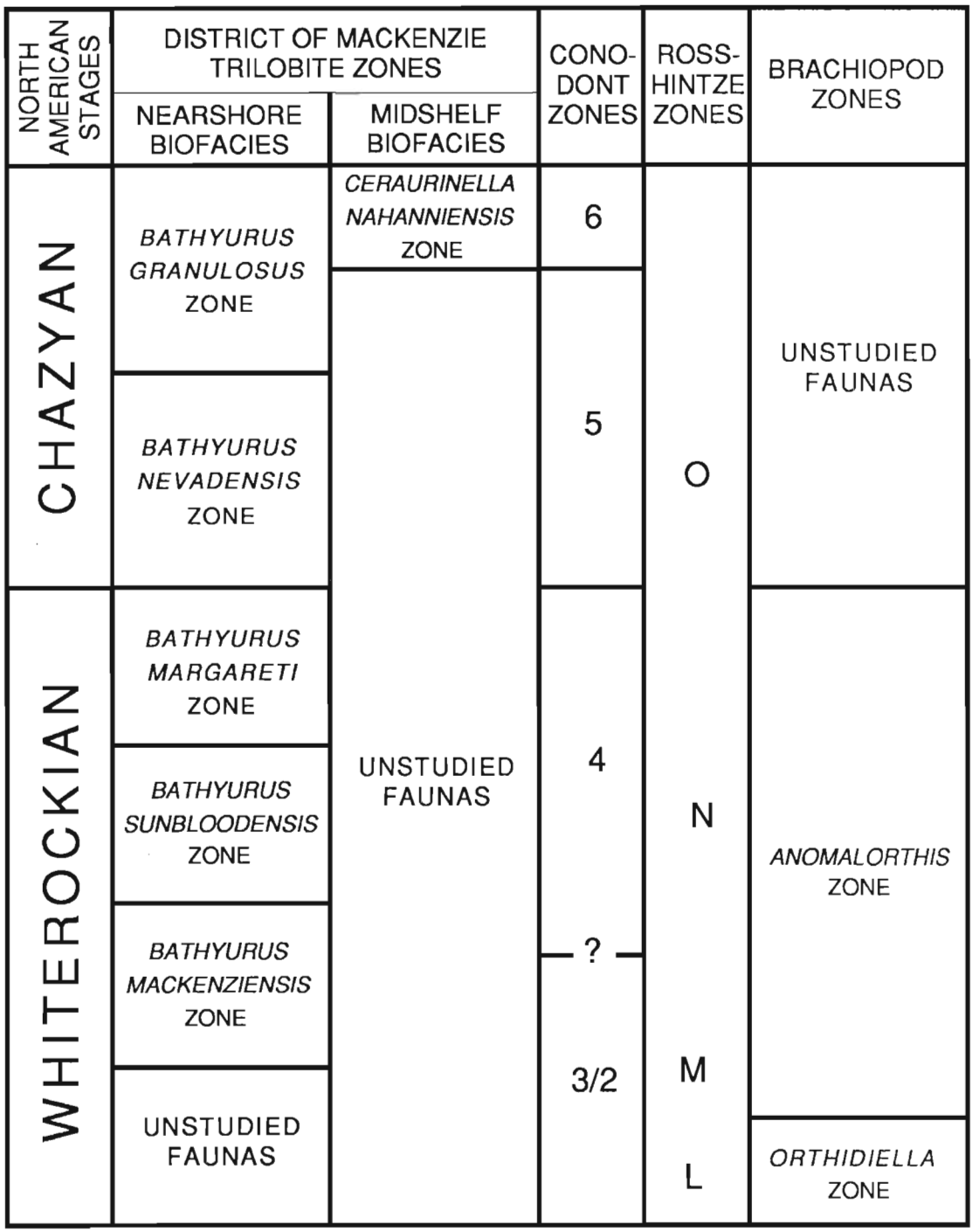

FIGURE 8. Sequence of trilobite and conodont zones in the study interval correlated with trilobite zones and brachiopod zones in Utah and Nevada.

water environment of deposition for these sections. Other evidence for shallow subtidal to intertidal conditions includes oncolites (Logan et al., 1964) and fenestral fabric (Shinn, 1983) throughout the studied sections.

The Whiterockian Nearshore Biofacies is compositionally very similar to Nearshore Biofacies in the Chazyan. Also, broadly comparable reef and slope biofacies occur in Whiterockian and Chazyan. However, a notable change occurs in the Midshelf Biofacies during this interval. Genera including *Pseudoolenoides, Pseudomera,* and *Xystocrania* dominate the Midshelf Biofacies in the middle and upper Whiterockian, but are unknown in Chazyan strata, although the related genus *Pliomerops* does occur in the Chayan. The Chazyan Midshelf Biofacies is dominated by genera including *Ceraurinella*, *Calyptaulax*, and *Isotelus*.

In the middle Whiterockian portion of sections S and G, the cheirurids *Xystocrania perforator*, and *Cydonocephalus* cf. *C. torulus*, and the pliomerid *Pseudomera barrandei* occur in some Nearshore Biofacies collections (Fig. 7). The same species of *Xystocrania* and *Pseudomera* occur in Nevada, Utah, Oklahoma, and Newfoundland with much more diverse trilobite faunas (without *Bathyurus*) that represent Midshelf and shelf margin biofacies (Fig. 7). A similar pattern was recorded by Ludvigsen (1975b, 1978) where some taxa that are characteristic of open shelf biofacies, including *Ceraurinella*, *Isotelus*, *Amphilichas*, and *Nanillaenus*, occur as rare elements in examples of the Nearshore Biofacies from the younger Esbataottine Formation.

TEMPORAL BIOSTRATIGRAPHY

Stadial nomenclature

The Middle Ordovician Champlainian Series in North America has traditionally been divided into four stages (in ascending order): the Whiterockian, Chazyan, Blackriveran, and Trentonian (Barnes et al., 1981), and this nomenclature is followed here. This thesis focuses primarily on the Whiterockian and Chazyan stages.

The Whiterockian Stage

The Whiterockian Stage (G. A. Cooper and B. N. Cooper *in* Cooper,1956) was based on assemblages of brachiopod genera in a composite type section through the Antelope Valley Limestone in central Nevada, and was intended to span the interval between the Canadian Series and the base of the Chazyan Stage. It became apparent that most of the five original brachiopod zones overlapped in time, and in its most recent form (Ross, 1970), *Orthidiella* Zone brachiopods, and correlative Zone L trilobites of Ross (1951) and Hintze (1953) are succeded by *Anomalorthis* Zone brachiopods, and Zone M and N trilobites (Fig. 8). Whiterockian trilobite faunas occur in western Newfoundland (Whittington, 1963, 1965), Oklahoma (Shaw, 1974), Utah and Nevada (Ross, 1951, 1967, 1970, 1972; Hintze, 1953), the Yukon Territory (Dean, 1973), as well as the District of Mackenzie.

One of the main points of debate concerning this stage has been the age of the upper part of the type Whiterock. Ross (1970) suggested that

the upper *Anomalorthis* Zone of the Antelope Valley Limestone was actually Blackriveran in age, but critical evaluation of the data has shown that this correlation is incorrect. Ross (1970) argued that because the upper *Anomalorthis* Zone contained the "Black River genera" *Bathyurus* and *Basilicus*, among others, it must be Blackriveran in age. However, subsequent work has shown that these genera range down into older strata. For example, Ludvigsen (1975a, b, 1978a, b, 1979) clearly demonstrated that *Bathyurus* is virtually restricted to the Nearshore Biofacies that persisted through both the Chazyan and Blackriveran stages. Moreover, he showed that *B. angustus*, and *B. nevadensis*, which are confined to the upper *Anomalorthis* Zone in the type Whiterock, occur in Chazyan strata from the District of Mackenzie. In addition, this study shows that *Bathyurus* occurs in strata dated as Whiterockian on the basis of other trilobites and conodonts. Furthermore, on the basis of conodont biostratigraphy, Bergstrom et al. (1973 *in* Ludvigsen, 1975a) concluded that the youngest part of the type Whiterock is in fact Chazyan in age.

More recently, Ross (*in* Ross et al. 1982), citing problems with overlap of the type Whiterock with Chazyan strata, proposed that the Whiterockian be elevated to series status encompasing what was formerly considered to be the Whiterockian and Chazyan stages. They did not establish any stadial nomenclature to replace the Whiterockian and Chazyan. Here, it is argued that there is sufficient faunal differentiation to allow the resolution of discrete Whiterockian and Chazyan stages, and these units are retained in the context of the Champlainian Series. Following Ludvigsen (1975a, b), conodont faunas 1 to 4 of Sweet et al.

(1971) are assigned to the Whiterockian Stage. The base of the Chazyan in the District of Mackenzie is marked by the coincident bases of the *Bathyurus nevadensis* Zone (Ludvigsen 1979) and conodont Fauna 5 of Sweet et al. (1971). This usage is practical and also satisfies the original intention of the Whiterockian Stage representing the interval between the Canadian (Ibexian) Series and the Chazyan Stage.

Whiterockian trilobite zones

In the study area, Whiterockian strata are representative of the Nearshore Biofacies, and the dominant trilobite species are absent from other regions where different biofacies are sampled. Therefore, existing zonations cannot be applied, and a new zonation is introduced in this thesis. Fortunately, a small number of taxa are shared with zonal schemes in other areas, and thus correlation is possible.

Ludvigsen (1975) identified poorly preserved specimens of *Pseudomera* sp., *Carolinites* sp., *Nileus* sp., and an illaenid from the base of his Section H. These trilobites occur with conodonts characteristic of Fauna 1, but it is not possible to define this fauna with any more detail.

Three new zones based on species of *Bathyurus* are established for Nearshore Biofacies strata of middle and late Whiterockian age. Strata yielding conodonts of Fauna 2-3 contain trilobites of the *Bathyurus mackenziensis* Zone, while the overlying interval of conodont Fauna 4 contains trilobites of the *Bathyurus sunbloodensis* Zone and the *Bathyurus margareti* Zone (Fig. 8). Trilobites herein assigned to ?*Bathyurus* sp. occur below the *B. mackenziensis* Zone in Section G, but this poorly preserved

fauna is inadequate to constitute the basis of a formal zone.

Bathyurus mackenziensis Zone

The lower boundary of this zone is based on the first appearance of *Bathyurus mackenziensis*. The zone also includes the following species: *Ludvigsenella ellipsepyga* n. gen., n. sp., *Xystocrania perforator*, *Pseudomera barrandei*, *Cydonocephalus* cf. *C. torulus*, *Ectenonotus* sp., and *Illaenus* sp.

Xystocrania perforator and *Pseudomera barrandei* also occur in Nevada, Utah, and Newfoundland, and suggest a correlation of the *B. mackenziensis* Zone with part of Zone N (*Anomalorthis* Zone) of Ross and Hintze (Fig. 8).

Assigned collections Lower Sunblood formation, Flood Creek (G-1745, G-1760, G-1825, G-1850, ?G-2170), Caribou Range (S-21, S-80, S-88, S-97, S-257, S-290), and Sunblood Range (BVF).

Conodonts Faunas 2-3 of Sweet et al. (1971; Tipnis et al., 1978, Table VIII).

Bathyurus sunbloodensis Zone

The first appearance of *Bathyurus sunbloodensis* marks the base of this zone. Because the *B. sunbloodensis* Zone does not occur in the same section as the underlying *B. mackenziensis* Zone, it is possible that other,

currently unrecognized trilobites occur between the ranges of *B. mackenziensis* and *B. sunbloodensis.* A single pygidium of *Cydonocephalus* cf. *C. torulus* was collected from P-55, and is the only non-bathyurid trilobite present in this zone.

Species from the *B. sunbloodensis* Zone are unknown outside of the District of Mackenzie. However, it is tentatively correlated with the upper part of Zone N of Nevada and Utah, based on its stratigraphic position and its conodont fauna.

Assigned collections Lower Sunblood Formation, Sunblood Range (P-10, P-30, P-55).

Conodonts Fauna 4 of Sweet et al. (1971; Tipnis et al., 1978, Table IX).

Bathyurus margareti Zone

The base of this zone is the first appearance of *Bathyurus margareti* immediately above *B. sunbloodensis* in Section P. This is the uppermost Whiterockian trilobite zone in the study area.

Assigned collections Lower Sunblood Formation, Sunblood Range (P-105, P-115), and Mary Range (B-360, B-400).

Conodonts Fauna 4 of Sweet et al. (1971; Tipnis et al., 1978, Table IX).

The Chazyan Stage and trilobite zones

Ludvigsen (1975b) thoroughly discussed the Chazyan Stage as it pertains to the study area, and established a trilobite zonation (Ludvigsen, 1979) that is followed here with some modification (Fig. 8). The Chazyan Stage in the study area includes strata containing conodonts of Fauna 5 and Fauna 6 of Sweet et al. (1971), and trilobites of the *Bathyurus nevadensis* Zone, *B. granulosus* Zone, and the *Ceraurinella nahanniensis* Zone (in ascending order). The *Bathyurus* zones are assigned to the Nearshore Biofacies, while the *C. nahanniensis* Zone is assigned to the Midshelf Biofacies.

Bathyurus nevadensis Zone (Ludvigsen, 1979)

This zone remains unchanged from Ludvigsen's treatment, except that *Pseudomera barrandei* is added to the list of included species. *B. nevadensis* itself is not present in the collections studied in this thesis but *B. angustus*, which is characteristic of the upper part of this zone, occurs in Section S.

Assigned collections Upper Sunblood Formation, Caribou Range (S-369, S-475), and (from Ludvigsen 1979) Mary Range (B-795, B-1005, B-1105).

Bathyurus granulosus Zone (Ludvigsen, 1979)

Ludvigsen's concept of this zone is retained in this thesis, but new material from the study area requires that the list of trilobites that occur in this zone be expanded to include *Ceraurinella nahanniensis*, *Encrinuroides rarus*, *Acanthoparypha evitti*, *Amphilichas* sp., and *Failleana* sp.

Assigned collections Upper Sunblood Formation, Funeral Range (Y-154, Y-186), and Sunblood Range (Z-208, Z-211, Z-240, Z-284, Z-296, Z-306). From Ludvigsen (1979), Upper Sunblood Formation, Mary Range (B-1165, B-1265, B-1315), Whittaker Range (?H-410), Flood Creek (G-2795), and Sunblood Range (P-1090, P-1127, P-1130, P-1187).

Ceraurinella nahanniensis Zone (Ludvigsen, 1979)

This zone was established by Ludvigsen for collections which represent a "Midshelf Biofacies interval" between the *Bathyurus granulosus* and the *B. ulu* zones, although Ludvigsen recognized that the *B. granulosus* and *C. nahanniensis* zones may in part be laterally equivalent. Four collections from Section Z (*B. granulosus* Zone) yielded small numbers of five species, including *Ceraurinella nahanniensis* itself, which characterize Ludvigsen's *C. nahanniensis* Zone. This suggests that the two zones are indeed laterally equivalent, and that superposition in Ludvigsen's sections reflects an interval of relative sea level rise. Therefore,

Ludvigsen's *Ceraurinella nahanniensis* Zone is herein redefined, and considered as the Midshelf Biofacies equivalent, at least in part, of the Nearshore Biofacies *B. granulosus* Zone (Fig. 8).

CHAPTER 3

SYSTEMATIC PALEONTOLOGY

TERMINOLOGY AND REPOSITORY

All of the material is housed at the Royal Ontario Museum, Toronto, Ontario, Canada. The terminology and classification basically follows that of Moore (1959) with the following additions and modifications.

Glabella - does not include the occipital ring

Palpebral area - in the Bathyuridae, that area bounded by the abaxial edge of the palpebral lobe and the axial furrow (Ludvigsen 1979)

Epsilon - the angle formed by the facial suture at the posterior end of the palpebral lobe (Richter and Richter 1949 *in* Ludvigsen 1979)

Gamma - the angle formed by the facial suture at the anterior end of the palpebral lobe (Richter and Richter 1949 *in* Ludvigsen 1979)

Order PTYCHOPARIIDA Swinnerton, 1915

Suborder ASAPHINA Salter, 1864

Superfamily ASAPHACEA Burmeister, 1843

Family ASAPHIDAE Burmeister, 1843

Subfamily ASAPHINAE Burmeister, 1843

Genus ***Basilicus*** Salter, 1849

Type species. *Asaphus tyrannus* Murchison, 1839 from Llandeilo strata of Wales (by original designation).

Basilicus sp.

Plate 1, Figures 1-4.

Occurrence Lower Sunblood Formation, Funeral Range (Y-5).

Material One partial cranidium, one complete pygidium.

Discussion The poorly preserved Sunblood cranidium is most similar to *Basilicus mckeei* Ross (1970, pl. 11, fig. 27, pl. 12, figs. 1-18) from the Antellope Valley Limestone (Zone N) in central and eastern Nevada, which differs in having a more forwardly expanding glabella.

Subfamily ISOTELINAE Angelin, 1854

Genus ***Isotelus*** DeKay, 1824

Type species. *Isotelus gigas* Dekay, 1824 from the Trenton Group, New York State (by original designation).

Isotelus cf. *I. harrisi* Raymond 1905

Plate 1, Figures 10-14.

1905 *Isotelus harrisi* Raymond, p. 343, pl. 12, figs. 3-7.

1968 *Isotelus harrisi* , Shaw, p. 57-58, pl. 21, figs. 13-16, pl. 22, figs.1-9 (see for synonymy).

Occurrence Upper Sunblood Formation, Sunblood Range (Z-211, Z-296). *Bathyurus granulosus* Zone.

Material Twelve hypostoma, five cranidia, two pygidia.

Description Cranidium is moderately convex and anterior portion slopes very gently to flattened border. Glabella is essentially parallel-sided and tapers gently ahead of palpebral lobes; axial furrows are very shallow, and are barely perceptible in front of palpebral lobes. Prominent palpebral lobes semi-circular in outline, and are situated just posterior of cephalic midlength. Anterior branches of facial suture diverge forward initially, then converge abruptly forward, running nearly parallel with, and close to

margin. Posterior branches diverge backward in a weakly sigmoid curve. Posterior portions of fixed cheeks are wide (tr.), and extend well beyond lateral extent of palpebral lobes.

Hypostome with rounded lateral margins and deeply notched posterior margin; notch occupies about one third of hypostome length (sag.). Prominent median body occupies anterior two thirds of hypostome and bears shallow, semi-circular maculae at postero-lateral corners.

Discussion The forward placement of the prominent palpebral lobes, the wide fixed cheeks of the cranidium, and the hypostome morphology distinguish this species from *I. parvirugosus* Chatterton and Ludvigsen (1976, pl. 2, figs. 1-42), of the Esbataottine Formation in the study area. The features listed above are closely comparible with those of*I. harrisi* Raymond from the Chazy Formation of New York, and *I.* sp., from the Simpson Group of Oklahoma, illustrated by Shaw (1968, pl. 21, figs. 13-16, pl. 22, figs. 1-9, and 1974, pl. 2, figs. 18, 24, 25 respectively). The lectotype of *I. harrisi* illustrated by Shaw (1968, pl. 21, figs. 13,14) appears to have more divergent anterior facial sutures, and axial furrows that converge more rapidly forward.

Suborder ILLAENINA Jaanusson, 1959

Superfamily ILLAENACEA Hawle & Corda, 1847

Family ILLAENIDAE Hawle & Corda, 1847

Subfamily ILLAENINAE Hawle & Corda, 1847

Genus ***Illaenus*** Dalman, 1827

Type species. *Entomostracites crassicaudata* Wahlenberg, 1821 from the Crassicaudata Limestone, Sweden (by original designation).

Illaenus sp. 1

Plate 1, Figures 17-19.

Occurrence Lower Sunblood Formation, Flood Creek (G-1825, G-2170). *Bathyurus mackenziensis* Zone.

Material 27 pygidia, 1 cranidium, 13 rostral plates.

Discussion Severely deformed specimens of *Illaenus* dominate a small collection (G-1825) that includes *Pseudomera barrandei* and *Bathyurus mackenziensis*. The lack of well preserved, complete material prevents a close comparison with other species.

Illaenus sp. 2

Plate 1, Figure 20.

Occurrence Upper Sunblood Formation, Caribou Range (S-369). *Bathyurus*

nevadensis Zone.

Material Five pygidia.

Discussion The availability of only a few deformed pygidia precludes a meaningful comparison with other species. *Illaenus sp.* 2 is the only trilobite other than *Bathyurus angustus* in the large collection from S-369.

Genus ***Bumastoides*** Whittington *in* Miller et al. 1954

Type species. *Ilaenus milleri* Billings, 1859 from the Trenton Group of Ontario (by original designation).

Bumastoides cf. *B. lenzi* Chatterton and Ludvigsen, 1976

Plate 1, Figures 5-9.

1976 *Bumastus (Bumastoides) lenzi* Chatterton and Ludvigsen, p. 35-37, pl. 5, figs. 1-31, 33-39; pl. 4, figs. 40-42 (?).

1978b *Bumastoides lenzi* , Ludvigsen, pl. 2, fig. 20.

1980 *Bumastoides lenzi* , Chatterton, p. 25-26, pl. 4, figs. 27-37; text-fig. 4 H.

Occurrence Lower Sunblood Formation, Funeral Range (Y-30).

Material Five pygidia, four cranidia.

Discussion The material from the Sunblood Formation is similar to *B. lenzi* Chatterton and Ludvigsen (1976, pl. 5, figs. 1-31, 33-39) from the Esbataottine Formation, but has slightly more anteriorly placed palpebral lobes, and a shorter (sag.) cranidium. It differs from *B. porrectus* (Raymond 1925, pl. 8, figs. 7, 8) in having a shorter cranidium, and more distinct lunettes and axial furrows. *B. milleri* (Billings) (illustrated by Wilson 1947, pl. 7, figs. 1a,b) has a longer cranidium than *B. porrectus*.

Subfamily BUMASTINAE Raymond, 1916

Genus ***Failleana*** Chatterton and Ludvigsen, 1976

Type species. *Failleana calva* Chatterton and Ludvigsen, 1976 from the Esbataottine Formation, District of Mackenzie (by original designation).

Failleana sp.

Plate 1, Figure 15.

Occurrence Upper Sunblood Formation, Sunblood Range (Z-296). *Bathyurus granulosus* Zone.

Material One partial cranidium.

Discussion The single incomplete cranidium is too poorly preserved to

allow a close comparison with other species.

Order PROETIDA Fortey and Owens, 1975

Family BATHYURIDAE Walcott, 1886

Subfamily BATHYURINAE Walcott, 1866

Discussion The occurrence of a new bathyurine genus in the Whiterockian Sunblood collections necessitates a brief review of the subfamily to which it is assigned. Whittington (1953), and Fortey (1979) provided the most recent treatments of the Bathyuridae, and from these, it is apparent that the Bathyurellinae have a short pygidial axis, and a very broad, smooth pygidial border, whereas the Bathyurinae are characterized by a long pygidial axis, and a relatively narrow pygidial border. The subfamily is here considered to include the following genera: *Bathyurus* Billings, 1859; *Bolbocephalus* Whitfield, 1890; *Petigurus* Raymond, 1913; *Acidiphorous* Raymond, 1925; *Eleutherocentrus* Clark, 1935; *Bathyurina* Poulsen, 1937; *Lutesvillia* Cullison, 1944; *Raymondites* Sinclair, 1944; *Peltabellia* Whittington, 1953; *Platyantyx* Whittington, 1953; *Strigigenalis* Whittington and Ross, *in* Whittington 1953; *Goniotelina* Whittington and Ross, 1953; *Catochia* Fortey, 1979; *Ludvigsenella* n. gen.

Ludvigsen (1975a, b) identified specimens as "*Goniotelina* " that are herein assigned to *Bathyurus sunbloodensis* n. sp. *Goniotelina williamsi* (Ross, 1951), the type species of *Goniotelina* Whittington and Ross, 1953, has been adequately described and illustrated by Ross (1951, pl. 14, figs. 16-22, 25), and Whittington (1953, pl. 68, figs. 11, 13-21), and the

following features of *G. williamsi* may be used to distinguish it from *B. sunbloodensis* and all other species of *Bathyurus* : the free cheek of *G. williamsi* has a slender, long, conical genal spine which, at the base, extends at an obtuse angle from the lateral margin so that the cephalic border is not extended on to the genal spine; the rostral plate has a cup-shaped anterior portion which is dissimilar to that of *Bathyurus* ; the hypostome has very shallow lateral and posterior border furrows, and narrow lateral and posterior margins with no shoulders; the pygidial axis is relatively broad, with a very long, tubular post-axial spine that is extended in part from the axis, and in part from the border.

Genus ***Bathyurus*** Billings, 1859

Type species *Asaphus? extans* Hall, 1847, from the Lowville Formation, Mohawk Valley, New York State.

Diagnosis A bathyurine genus with inflated glabella that is parallel-sided, or expands slightly forward. In some species, the axial furrows are bowed outwards between the palpebral areas. Two or three pairs of faint to firm, obliquely disposed, lateral glabellar furrows are present. Genal spines are long and tapering. Hypostome is quadrate in outline with narrow convex borders, deep border furrows, firm maculae, and anterior wings. Thin, crescentic rostral plate is strongly flexed (sag.) and waisted by connective sutures. Pygidium is semi-circular to sub-triangular, with deep axial furrows, four interpleural furrows, and flattened borders.

Discussion Much has been contributed to the knowledge of this genus since Whittington (1953) discussed several species in detail. Ludvigsen (1975a, b, 1978a, b, 1979) described, illustrated and proposed phylogenies for species of *Bathyurus* from the study area, and also examined the types of six species that occur outside of the District of Mackenzie.

Bathyurus angustus Ross, 1970

Plate 1, Figures 21-49.

1970 *Bathyurus acutus* subsp. *angustus* Ross, p. 86, pl. 16, figs. 6 - 12.

1979 *Bathyurus angustus* , Ludvigsen, p. 19-20, pl. 2, figs. 1-9.

Holotype Incomplete cranidium (USNM 169877) from the Lehman Formation, Egan Range, Nevada, illustrated by Ross (1970, pl. 16, figs. 9-11).

Occurrences Lehman Formation and Kanosh Shale, Egan Range, central Nevada; Antelope Valley Limestone, Hot Creek Canyon and Pahranagat Range, central Nevada; Upper Sunblood Formation, Mary Range (B-795), and Caribou Range (S-369, S-475). Middle and upper *Anomalorthis* Zone (in Nevada), *Bathyurus nevadensis* Zone (in Canada).

Material 244 pygidia, 57 cranidia.

Discussion *B. angustus* was adequately described by Ross (1970). Ludvigsen (1979) concluded that *B. angustus* constitutes a species distinct from *B. acutus* , and that revision is accepted here. These are the only two post-Whiterockian species of *Bathyurus* with terminal pygidial spines.

The large numbers of *B. angustus* include many juvenile cranidia and pygidia, and thus permit an assessment of the late meraspid and holaspid ontogeny of the species. The development is very similar for all species of *Bathyurus* dealt with in this thesis, and therefore the ontogeny of *B. angustus* serves as a general guide to the growth of other species.

The following changes occur with increasing size in cranidia (Pl. 1, Figs. 21, 22, 38, 39, 41, 42): The preglabellar field decreases in length (sag. and exsag.) with respect to the glabella; and the lateral glabellar furrows become shallower.

The pygidia undergo the following changes with increasing size (Pl. 1, Figs. 29-32, 47, 48): The medial nodes on the axial rings become less prominent; and the interpleural furrows on the pygidial border become effaced. The terminal pygidial spine on *B. angustus* remains relatively long throughout ontogeny. This is in contrast to other species with terminal spines (*B. mackenziensis* n. sp., *B. sunbloodensis* n. sp., *B. margareti* n. sp., *B. acanthapyga* n. sp.) where relative spine length decreases with increasing pygidial size (see Pl. 3, Figs 8, 9, 29; Pl.4, Figs. 16, 18, 38; Pl. 5, Figs. 10, 14, 21; Pl. 6, Figs. 8, 11, 12 respectively).

Bathyurus granulosus Ludvigsen, 1979

Plate 2, Figures 1-37.

1975a *Bathyurus* sp. 1 Ludvigsen, pl. 1, figs. 20-23.

1975b *Bathyurus* sp. 1 Ludvigsen, p. 152-154, pl. 1, figs. 1-46, pl. 5, fig. 2.

1979 *Bathyurus granulosus* Ludvigsen, p.18, pl. 3, figs 1-46, figure 10B.

Holotype An incomplete cranidium (GSC 40336) from the upper Sunblood Formation, Sunblood Range (P-1090), illustrated by Ludvigsen (1979), pl. 3, figs. 1-3.

Occurrences Upper Sunblood Formation, Mary Range (B-1265, B-1295, B-1315), Sunblood Range (P-1090, P-1127, P-1187, Z-211, Z-240, Z-284, Z-306), Flood Creek (G-2795), Whittaker Range (?H-410), and Funeral Range (Y-154). *Bathyurus granulosus* Zone.

Material 131 right-side free cheeks, 124 left-side free cheeks, 75 pygidia, 47 cranidia.

Discussion *B. granulosus* was described by Ludvigsen (1979). The specimens from sections Y and Z show some variation in prominence of the posterolateral spines on the hypostome (compare Pl. 2, Figs. 4, 12, 11, 20, 26, 33). Although the spines on some specimens here are relatively

prominent compared to those on specimens from the type locality, all other features are are identical those of the holotype. For this reason, the specimens illustrated herein are placed in *B. granulosus* .

Bathyurus mackenziensis n. sp.

Plate 3, Figures 1-41.

Holotype A nearly complete pygidium (ROM 47650) from S-88, illustrated herein on Pl. 3, Figs. 33-35.

Name From the Mackenzie Mountains.

Diagnosis A species of *Bathyurus* with a parallel-sided glabella. Middle portion of rostral plate is narrow. A rectangular hypostome has well developed posterolateral spines. Very broad and well defined pygidial border is extended into a short posterior spine which is lost in large adults. Each axial ring on the pygidium has a pair of medial nodes.

Occurrences Lower Sunblood Formation, Flood Creek (G-1745, G-1760, G-1825, G-1850, ?G-2170), base of Virginia Falls (BVF), and Caribou range (S-21, S-80, S-88, S-97, S-257, S-260, S-290) . *Bathyurus mackenziensis* Zone.

Material 250 pygidia, 224 cranidia.

Description Glabella is parallel-sided. Moderately deep axial furrows are slightly bowed outward opposite palpebral lobes. Preglabellar field is narrow sagittally, but widens at anterolateral corners so that anterior margin is broadly prow-shaped. Very faint 1s furrow extends straight inwards from axial furrow at a point near half the length (exsag.) of palpebral area, then curves sharply backwards to become posteriorly directed, ending just ahead of occipital furrow. Extremely faint 2s furrow is roughly parallel to 1s. Semicircular palpebral area stands below crest of glabella; crescentic palpebral lobe is defined by shallow palpebral furrow. Moderately deep, transverse occipital furrow defines lenticular occipital ring. Anterior branch of facial suture initially extends forward and outward at an acute angle to glabellar margin before curving sharply inward. Suture crosses anterior margin just outside of a point in exagittal line with axial furrow.

Free cheek slopes steeply below eye to weakly convex cephalic border which sharply narrows posteriorly and terminates just in front of the tip of long, gradually tapering genal spine.

Rostral plate has triangular, very gently curved (tr. and sag.) anterior portion with straight rostral suture and strongly anteriorly divergent branches of connective suture, and a wide (tr.), strongly curved (tr.), crescent-shaped posterior portion with a posteriorly divergent hypostomal suture

Hypostome is sub-trapezoidal in outline. Central body is strongly inflated; posterior portion has deep, posteriorly convergent lateral border furrows that become wider and shallower where they join posterior border

furrow. Posterior border furrow straight, becoming narrower (sag.) and shallower medially. Pair of deep, lenticular maculae are located on margin of central body. Posteriorly converging lateral borders with weak shoulders terminate at well-developed, stout, posterolateral spines. Posterior margin is bowed very faintly towards rear. Pair of high, slender anterior wings are directed outwardly and vertically.

Pygidium is sub-triangular to sub-semicircular in outline. Strongly vaulted axis occupies about one quarter pygidial width, with four axial ring furrows; first four or five axial rings have a pair medial nodes. Deep axial furrows converge slightly backward, then fade out at posterior end of axis. Tip of axis bears a pair of rounded protuberances. Pleural field is crossed by four moderately deep interpleural furrows, and has a very broad, smooth border, and a distinct border furrow. First two or three pleural furrows are expressed only on border and do not extend to margin. On all but the largest adults, the margin carries a short, pointed posterior spine; a carina connects the spine with axial tip. Broad, flat doublure extends inward as far as border furrow.

Prosopon on dorsal surface of exoskeleton is very finely granulose.

Discussion *B. mackenziensis* compares most closely with *B. margareti* n. sp., which differs from *B. mackenziensis* in the following ways:

1. The glabella is bowed outward between the anterior ends of the palpebral areas.
2. The waisted middle portion of the rostral plate is much wider (tr.).
3. The border furrow on the pygidium is effaced.

4. The pygidial doublure may be notched medially beneath the axis. *B. sunbloodensis* n. sp., Pl. 4, Figs.1-45, and *B. acanthapyga* n. sp., Pl. 5, Figs. 30-42 and Pl. 6, Figs. 1-21, represent a morphologically similar group that is markedly different from *B. mackenziensis* in having a prosopon of coarser granules on the exoskeleton, and a broader pygidial axis which has single medial nodes, or else lacks medial nodes on the axial rings. *Bathyurus acutus* Raymond (see Ross 1970, pl. 16, figs. 1-5), and *B. angustus* Ross are the only other species of *Bathyurus* with a terminal pygidial spine. *B. acutus* differs from all of the species considered here in possessing a glabellar prosopon of fine irregular wrinkles.

Bathyurus sunbloodensis n. sp.
Plate 4, Figures 1-45.

1975a '*Goniotelina*' sp. Ludvigsen, pl. 1, figs. 11 - 13.

Holotype A nearly complete cranidium (ROM 47678) from P-55, illustrated on Plate 4, Figures 32-34.

Name From the Sunblood Formation.

Diagnosis A species of *Bathyurus* with parallel-sided glabella. Anterior border is short sagittally and at antero-lateral corners. Lateral glabellar furrows are extremely faint or effaced. Occipital ring bears a medial node. Rectangular hypostome with very tiny posterolateral spines or none. The

pygidial axis is relatively wide; anterior most one or two axial rings bear a single median node. Relatively narrow border without a border furrow; a stout posterior spine extended from the border is absent on large adults. Cranidium has a prosopon of fine and coarse granules, with fine, irregular wrinkles on palpebral areas; pygidium has small asymmetric chevron-shaped scales.

Occurrences Upper Sunblood Formation, Sunblood Range (P-10, P-30, P-55). *Bathyurus sunbloodensis* Zone.

Material 182 pygidia, 120 cranidia.

Description Glabella is parallel-sided and outlined by deep axial furrows. Preglabellar field short sagittally, very narrow at anterolateral corners; anterior margin broadly rounded. Lateral glabellar furrows extremely faint or effaced; 1s extends obliquely inwards from axial furrow at a point just ahead of mid length (exsag.) of palpebral area; 2s runs parallel to 1s, from axial furrow at a point opposite anterior end of palpebral area. Palpebral area sub-semicircular in outline; crescentic, palpebral lobe well-defined by palpebral furrow. Deep, transverse occipital furrow defines lenticular occipital ring with a median node at the posterior edge. Anterior branch of facial suture extends straight forward at gamma, then curves inwards sub-parallel with glabellar margin.

Below eye, free cheek slopes steeply to flat cephalic border which narrows posteriorly to become a faint furrow between a point opposite

mid-length (exsag.) of palpebral lobe and tip of moderately long and tapering genal spine.

Rostral plate has triangular, very gently curved (tr. and sag.) anterior portion with straight rostral suture, and strongly anteriorly divergent branches of connective suture. Wide (tr.), strongly curved (tr.) crescent shaped posterior portion has posteriorly divergent hypostomal suture.

Hypostome is sub-trapezoidal in outline. Central body is inflated; posterior portion has deep, posteriorly convergent lateral border furrows that become wider and shallower where they join posterior border furrow. Posterior border furrow gently curved, becoming narrower (sag.) and shallower medially. Pair of deep, lenticular maculae located on margin of central body. Lateral borders with pronounced shoulders opposite maculae. Juncture of lateral and posterior margins producing very minute posterolateral spines. Posterior margin very faintly bowed towards rear.

Pygidium sub-triangular to sub-semicircular in outline. Strongly vaulted axis occupies about one-third pygidial width at anterior margin, tapers towards rear; two or three axial ring furrows define axial rings; the first one or two axial rings bear a medial node. Deep axial furrows become shallow at posterior end of axis. Pleural field is crossed by four deep interpleural furows. Lateral border narrow (tr.), border furrow obsolete; four successively shallower pleural furrows expressed only on border, do not extend to margin. Margin converges to produce a short, stout, pointed terminal spine; a carina on the spine joins it with axial tip.

Microsculpture on dorsal surface of glabella, occipital ring and free cheek consists of coarse and fine granules; palpebral areas with fine,

irregular wrinkles; pygidium with small, assymmetric, chevron-shaped scales.

Discussion Ludvigsen (1975a, b) assigned specimens, without discussion, to "*Goniotelina*". However, it is apparent that *G. williamsi*, the type species of *Goniotelina* (see discussion of Bathyurinae) differs considerably from Ludvigsen's material which is herein assigned to *Bathyurus sunbloodensis* n. sp.

B. sunbloodensis compares closely with *B. acanthapyga* which differs from *B. sunbloodensis* in the following ways:

1. The glabella is bowed outwards between the palpebral lobes.
2. The occipital ring lacks a medial node.
3. Posterolateral spines are lacking on the hypostome.
4. The prosopon lacks coarse granules.

Bathyurus margareti n. sp.

Plate 5, Figures 1-29.

1975a '*Bathyurus*' sp. Ludvigsen, pl. 1, figs. 15 -17.

Holotype A nearly complete cranidium (ROM 47687) from B-360, illustrated on Plate 5, Figures 1-3.

Name For my wife, Margaret.

Diagnosis A species of *Bathyurus* with expanding glabella between palpebral areas. Middle portion of rostral plate is very broad. Rectangular hypostome has well developed posterolateral spines. Sub-semicircular pygidium has a wide border with a very faint border furrow, and may have a medially notched doublure beneath the axis.

Occurrences Lower Sunblood Formation, Mary Range (B-360, B-400), and Sunblood Range (P-105, P-115). *Bathyurus margareti* Zone.

Material 110 pygidia, 42 cranidia.

Discussion *B. margareti* occurs immediately above *B. sunbloodensis* in Section P. Variability in pygidial prosopon is evident in the collections from Section P: some pygidia assigned to *B. margareti* have a single median node on the first axial ring, while others have paired nodes in the same position. However, pygidia assigned to this species from Section B bear a pair of median nodes on the first axial ring. Among other species, a single median node on adult pygidia occurs elsewhere only in *B. sunbloodensis*, and its presence in *B. margareti* suggests that this species may have been derived from *B. sunbloodensis*. *B. acanthopyga* n. sp. has a much more waisted rostral plate, and a sub-triangular pygidium that lacks medial nodes on the axis.

Bathyurus acanthopyga n. sp.

Plate 5, Figures 30-42, Plate 6, Figures1-21 .

Holotype A nearly complete cranidium (ROM47706) from Y-5, illustrated on Plate 5, Figures 30-33.

Name From *acantho* - thorn (Greek) in reference to the pygidial spine.

Diagnosis A species of *Bathyurus* with glabella that is bowed outwards between the palpebral areas. The preglabellar field is moderately wide (sag.) medially, becoming wider (exsag.) at anterolateral corners. The occipital ring lacks a medial node. Posterolateral spines are absent on the hypostome. The pygidial axis is relatively wide; single medial node is present only on anteriormost axial ring of small holaspids. A slender, pointed, terminal pygidial spine is relatively long on small individuals, but short on large holaspids. The entire dorsal surface of the exoskeleton has a prosopon of fine granules.

Occurrences Upper Sunblood Formation, Funeral Range (Y-5, Y-32).

Material 176 pygidia, 76 cranidia.

Discussion The degree to which *B. acanthopyga* resembles *B. sunbloodensis* in pygidial shape, width of the pygidial axis, and the presence of a single medial node on the first axial ring of juvenile holaspids, suggests that the

two species are closely related. *B. acanthopyga* occurs below the *B. granulosus* Zone in Section Y, but a more refined correlation with other zones is not possible because: no other species of *Bathyurus* occurs in Section Y; *B. acanthopyga* does not occur in any other section; and there is no conodont data for Section Y.

?*Bathyurus* sp.

Plate 6, Figures 22-25.

Occurrence Lower Sunblood Formation, Flood Creek (G-1425).

Material Numerous deformed fragments.

Discussion The severely deformed bathyurine material from G-1425 appears to have only three pairs of pleural furrows on the pygidium. For this reason it is questionably assigned to *Bathyurus*.

Genus ***Ludvigsenella*** new genus

Type species *Ludvigsenella ellipsepyga* n. gen., n. sp., from the lower Sunblood Formation, Sunblood Range and Caribou Range, District of Mackenzie.

Name For Rolf Ludvigsen, who has worked extensively on trilobites from the District of Mackenzie.

Diagnosis A bathyurine genus with a forwardly expanding glabella lacking lateral glabellar furrows. The preglabellar furrow is effaced medially, and a preglabellar field is absent; anterior margin is broadly rounded. The posterior palpebral lobe is recurved forward. The relatively short (sag.) pygidium is semi-elliptical in outline with three pairs of pleural furrows - the first two pairs are firmly impressed, while the third is nearly obsolete. On small individuals, a fine, tubular spine protrudes from the margin behind the axis. The prosopon consists of tubercles and coarse granules on the cranidium, fine irregular wrinkles on the hypostome, and fine granules on the pygidial axis.

Discussion Morphologic characters of the pygidium are particularily important in separating *Ludvigsenella* from closely related bathyurine genera: the pygidium is semi-elliptical in outline, with only two pairs of firmly impressed pleural furrows, and, on small individuals, a short, tubular spine extends from the margin behind the axis. The pygidium of *Goniotelina* is longer, sub-triangular, and generally has three to four pairs of pleural furrows. The pygidium of *Acidiphorous* is very similar to that of *Goniotelina*, with only two pairs of pleural furrows, and with a long, tubular spine extended in part from the axis and in part from the pleural field. In both genera, the spine may extend only from the pleural field. *Bathyurus* has a pygidium with a markedly different appearance, with four pairs of pleural furrows; where a terminal pygidial spine is present, it extends only from the border.

The posterior palpebral lobes of *Ludvigsenella* are recurved forward. This feature occurs elsewhere only in *Acidiphorous* (see Whittington, 1965, pl. 44, fig. 5). The anterior glabellar lobe is moderately convex in lateral view, and the anterior border is broadly rounded. The preglabellar furrow is effaced medially. By contrast, *Goniotelina* has a markedly prow-shaped anterior border, and a relatively long preglabellar field. *Acidiphorous* Raymond, has a very convex anterior glabellar lobe, a slightly prow-shaped anterior border, and a short preglabellar field. *Bathyurus* has a strongly convex anterior glabellar lobe, with a rounded anterior border, and short to long preglabellar field.

The genal spine is a smooth continuation of the lateral border, similar to that of *Bathyurus* and some species of *Acidiphorous*, and unlike some species of *Goniotelina* (see *G. williamsi* and *G. brighti* in Hintze 1953) in which the base of the genal spine is at an angle to the lateral border.

Ludvigsenella ellipsepyga n. gen., n. sp.
Plate 6, Figures 26-38, Plate 7, Figures 1-15.

1970 *Goniotelina?* sp., Ross, p. 87, pl. 16, figs. 13, 14, 17.

Holotype A nearly complete cranidium (ROM 47733) from BVF, illustrated on Plate 6, Figures 27, 28.

Name In reference to the elliptical shape of the pygidium.

Diagnosis The diagnosis for the genus serves as the diagnosis for the only species, *L. ellipsepyga* .

Occurrences High Pogonip beds, Steptoe, Nevada; Lower Sunblood Formation, Caribou Range (S-80, S-88, S-97, S-290) and Sunblood Range (BVF). Upper *Anomalorthis* Zone (Nevada), *B. mackenziensis* Zone (Canada).

Material 59 cranidia, 50 pygidia.

Description Forwardly expanding, unfurrowed glabella is moderately vaulted with nearly flat (tr.) crest; front edge of anterior lobe descends vertically to anterior border. Axial furrows deep, become shallow at juncture with preglabellar furrow which is effaced medially. Preglabellar field lacking, anterior border furrow very gently curved (exsag.), anterior margin broadly rounded. Deep occipital furrow slightly bowed forward; occipital ring lenticular in shape. Palpebral area sub-semicircular in outline, with rounded, anteriorly directed notch where lobe is posteriorly joined with fixed cheek; palpebral furrow firmly impressed, defines thin, tubular palpebral lobe. Deep, nearly straight posterior border furrow dies out in front of inside curvature of genal spine. Anterior branch of facial suture subparallel with axial furrow, obliquely crosses anterior margin in front of point where preglabellar furrow dies out. Posterior branch of facial suture proceeds backwards from notch in palpebral area, then curves sharply outwards, and continues backwards and outwards, intersects posterior margin half way between axial furrow and lateral margin.

Cranidium with prosopon of coarse and fine tubercles, gradually replaced on anterior glabellar lobe by terrace ridges.

Free cheek with steeply sloping field below eye, and a tubular cephalic border. Lateral border furrow firmly impressed, continues to tip of carinate, inwardly curved genal spine.

Hypostome rectangular in outline. Central body inflated; deep posteriorly convergent lateral border furrows join nearly straight posterior border furrow. A pair of deep, lenticular, obliquely disposed maculae located on margin of central body about two thirds the length of hypostome from anterior margin. Lateral borders without shoulders join smoothly with nearly straight posterior border, no trace of posterolateral spines. High anterior wings are outwardly and vertically directed.

Pygidium semi-elliptical in outline. Moderately vaulted axis nearly one third pygidial width at anterior margin, with two or three distinct axial rings; anterior most axial ring has a pair of median nodes. Deep axial furrows converge backwards, become shallow at posterior end of axis. Inner part of pleural field is nearly horizontal, outer portion declines at a steep angle to the margin; smooth border lacks a border furrow. Three pairs of interpleural furrows - the first two pairs are firmly impressed, while the third is nearly effaced. A single pleural furrow is expressed on the border opposite a point between the anterior two interpleural furrows. On small individuals, a slender, tubular spine protrudes from the margin behind the axis; the size of this spine is reduced in larger individuals, and is obsolete on the largest pygidia. Axis with prosopon of fine granules, remainder is smooth.

Family TELEPHINIDAE Marek, 1952

Genus ***Phorocephala*** Lu, in Lu et al., 1965

Type species. *Phorocephala typa* Lu, in Lu et al., 1965 from the Siliangssu Formation of China (by original designation).

Phorocephela cf. *P. pinguimitra* (Chatterton and Ludvigsen, 1976)

Plate 7, Figures 16, 17.

1975a *Carrickia* n. sp. Ludvigsen, pl. 3, figs. 13, 14.

1976 *Carrickia pinguimitra* Chatterton and Ludvigsen, p. 44-47, pl. 17, figs. 1-50.

1978 *Carrickia pinguimitra* , Ludvigsen, pl. 1, fig. 8.

1980 *Phorocephala pinguimitra* , Chatterton, p. 30, pl. 7, figs 1-27, text-fig. 5 H-K.

Occurrence Upper Sunblood Formation, Sunblood Range (Z-208). *Bathyurus granulosus* Zone.

Material One pygidium, six left-side free cheeks.

Discussion The pygidium and free cheeks closely resemble those illustrated by Chatterton and Ludvigsen (1976, pl.17, figs. 1, 2, 18, 22, 26, 41, 44, 45, 46).

Order PHACOPIDA Salter, 1864

Suborder CHEIRURINA Harrington and Leanza, 1957

Family CHEIRURIDAE Hawle and Corda, 1847

Subfamily CHEIRURINAE Hawle and Corda, 1847

Genus ***Ceraurinella*** Cooper, 1953

Type species. *Ceraurinella typa* Cooper, 1953 from the Edinberg Formation of Virginia (by original designation).

Ceraurinella nahanniensis Chatterton and Ludvigsen, 1976

Plate 7, Figures 18-20.

1975 *Ceraurinella* n. sp. 2, Ludvigsen, pl. 3, figs. 16, 17.

1976 *Ceraurinella nahanniensis* Chatterton and Ludvigsen, p. 55 -57, pl. 9, figs. 1 - 35, text-fig. 9.

1979 *Ceraurinella nahanniensis*, Ludvigsen, p. 23, pl. 7, figs. 1 - 21.

Holotype Complete cranidium (GSC 40399) from the lower Esbataottine Formation (P-1497), illustrated by Ludvigsen (1975a), pl. 3, fig. 16, and Chatterton and Ludvigsen (1976), pl. 9, figs. 1 - 3.

Occurrence Lower Esbataottine Formation, Sunblood Range and Whittaker Range; upper Sunblood Formation, Sunblood Mountain (Z-211). *Ceraurinella nahanniensis* Zone, *Bathyurus granulosus* Zone.

Material One incomplete cranidium.

Discussion This species has been fully described by Chatterton and Ludvigsen (1976). The occurrence of a single cranidium of *C. nahanniensis* in Z-211, a small collection of 25 individuals dominated by *Bathyurus granulosus*, demonstrates that some mixing of taxa from adjacent biofacies does occur, and that the Midshelf Biofacies *C. nahanniensis* Zone is, at least in part, equivalent to the Nearshore Biofacies *B. granulosus* Zone.

Ceraurinella sp.

Plate 7, Figure 21.

Occurrence Lower Sunblood Formation, Funeral Range (Y-30).

Material One partial cranidium, three right side free cheeks, two partial pygidia.

Discussion The poorly preserved and incomplete material from Y-30 precludes a meaningful comparison with any species of *Ceraurinella* .

Subfamily ACANTHOPARYPHINAE Whittington and Evitt, 1954

Genus ***Acanthoparypha*** Whittington and Evitt, 1954

Type species. *Acanthoparypha perforata* Whittington and Evitt, 1954 from the Edinberg Formation of Virginia (by original designation).

Acanthoparypha evitti Chatterton and Ludvigsen, 1976

1975a *Acanthoparypha* n. sp. 1, Ludvigsen, Pl. 3, figs. 20, 21.

1976 *Acanthoparypha evitti* Chatterton and Ludvigsen, p. 59-62, Pl. 10, figs. 1-41.

1978b *Acanthoparypha evitti*, Ludvigsen, Pl. 2, fig. 23.

1979 *Acanthoparypha evitti*, Ludvigsen, p. 40, Text fig. 17.

Holotype An incomplete cranidium (GSC 40403) from the Esbataottine Formation, Sunblood Range (P-1497), illustrated by Chatterton and Ludvigsen (1976), pl. 10, figs. 1-4.

Occurrences Lower Esbataottine Formation, Sunblood Range; Upper Sunblood Formation, Sunblood Mountain (Z-306). *Bathyurus granulosus* Zone, *Ceraurinella nahanniensis* Zone.

Material Two cranidia, one pygidium.

Discussion A small, nearly complete pygidium, and two incomplete cranidia

closely resemble specimens illustrated by Ludvigsen (1975a, 1978b, 1979) and Chatterton and Ludvigsen (1976). The material from Z-306 has not been illustrated because it is very delicately silicified, and would not have remained intact through the photography process.

Subfamily SPHAEREXOCHINAE Opik, 1937

Genus ***Xystocrania*** Whittington, 1965

Type species. *Cheirurus perforata* Billings, 1865 from the Table Head Formation, western Newfoundland (by original designation).

Xystocrania perforator (Billings 1865)

Plate 7, Figures 22-36.

1865 *Cheirurus perforator* Billings, p. 287, fig. 275.

1925 *Nieszkowskia perforator*, Raymond, p. 146-147.

1925 *Nieszkowskia excelsus* Raymond, p. 145-146, Pl. 10, fig. 8.

1952 *Kawina? unicornica* Hintze, p. 179-181, Pl.28, figs. 1-5.

1965 *Xystocrania perforator*, Whittington, p. 413-414, Pl. 61, figs. 1-10 only [fig. 11 = *X. glaucus*].

1970 *Xystocrania* cf. *X. perforator* Ross, p. 89-90, pl. 17, figs. 3-7, 10.

Holotype Incomplete cranidium (GSC 684) from the Table Cove Formation, illustrated by Billings, 1865, fig. 275, and Whittington, 1965, pl. 61, figs.

1, 3 and 6.

Occurrences Table Point and Table Cove formations, Newfoundland; Pogonip Group, Ibex area, Utah; Antelope Valley Limestone, Ikes Canyon, Toquima Range, Nevada; lower Sunblood Formation, Caribou Range (S-80, S-88, S-97, S-290). *Anomalorthis* Zone/Zone N (Nevada and Utah), *Bathyurus mackenziensis* Zone (Canada).

Material 132 cranidia, 110 pygidia.

Discussion Hintze (1952) recognized that the medial glabellar spine and shallow ls and 2s furrows of *Kawina ?unicornica* , from the Pogonip beds, Utah, (Hintze , 1952, pl. 28 figs. 1-5) were most similar to those of Billings' (1865) original types of *X. perforator* from Newfoundland. Whittington (1965) transfered *K? unicornica* to *Xystocrania* and suggested that it could be separated from *X. perforator* on the basis of lower glabellar convexity and a more rounded hypostome outline. However, the difference in glabellar convexity between the Utah and Newfoundland specimens is small, considering the variation between illustrated specimens from each location, and is not considered to be sufficient for specific differentiation. Whittington's (1965, Pl. 61, fig. 11) assignment of a single hypostome to *X. perforator* is, at best, questionable. The hypostome was collected from a bed yielding *X. glaucus*, rather than from an horizon bearing *X. perforator* ; it is therefore assigned to *X. glaucus* . The hypostome of *X. perforator* is illustrated herein (Plate 7, Figure 23) and is identical to that attributed by

Hintze (1952, pl. 28, fig. 3) to *X. unicornica*. Hintze's (1952) *X. unicornica* is herein considered to be a junior synonym of *X. perforator* (Billings 1865). *Xystocrania* cf. *X. perforator* from the Antelope Valley Limestone (Ross 1970) is also assigned to *X. perforator.*

Ontogeny The size range of specimens in the Sunblood collections allows the ontogeny of this species to be recognized and described for the first time. With an increase in size, the cranidial prosopon of granules becomes less dense and relatively less coarse (Pl. 7, Figs. 22, 24-26, 31-33.) During the course of the ontogeny, the pygidial spines become relatively shorter, and the third axial ring becomes less distinct (Pl. 7, Figs. 35, 36, 29).

Genus ***Cydonocephalus*** Whittington, 1963

Type species. *Cydonocephalus griphus* Whittington, 1963 from a Middle Ordovician boulder in the conglomerate at Lower Head, western Newfoundland (by original designation).

Cydonocephalus cf. *C. torulus* Whittington, 1963

Plate 7, figures 37-47.

1975 *Kawina* sp. Ludvigsen, Pl. 1, fig. 19.

1979 *Kawina* sp. Ludvigsen, Pl. 21, figs. 49, 50.

Occurrences Lower Sunblood Formation, Sunblood Range (P-55), and Caribou Range (S-80, S-88, S-97, S-290). *Bathyurus mackenziensis* Zone,

Bathyurus sunbloodensis Zone.

Material 11 cranidia, 18 pygidia.

Discussion A pygidium is assigned correctly to *Cydonocephalus* for the first time. Species of *Cydonocephalus* are commonly associated with *Kawina* and *Xystocrania* (Whittington 1963, Ross 1970, this thesis). The pygidia of these three related genera are similar, so it is not surprising that pygidia of *Cydonocephalus* have, in the past, been misassigned to *Kawina* (Ross 1970, Pl. 18, figs. 16-18; Ludvigsen 1975a, 1979). The pygidium of *Cydonocephalus* is distinguished from that of *Kawina* in posessing three, rather than four, axial rings, and from *Xystocrania* in having the third axial ring fully defined by axial furrows. The cranidia from the District of Mackenzie most closely resemble *C. torulus* from the Cow Head boulder at Lower Head, Newfoundland, described and well-illustrated by Whittington 1963, p. 100-101, Pl. 26, figs. 1-4, 6, 9; Pl. 27, figs. 16-18; Pl. 28, figs. 5-8; and Pl. 29, figs. 1-7, 9. The Sunblood material differs from these in having prosopon of finer granules.

Family PLIOMERIDAE Raymond, 1913

Subfamily CYBELOPSINAE Fortey, 1979

Genus ***Ectenonotus*** Raymond, 1920

Type species. *Amphion westoni* Billings 1865 from the Mystic Conglomerate, Quebec (by original designation).

Ectenonotus sp.

Plate 8, Figure 24.

Occurrence Lower Sunblood Formation, Caribou Range (S-97). *Bathyurus mackenziensis* Zone.

Material One partial cranidium, three partial pygidia.

Discussion The fragmental material prevents a close comparison with any described species of *Ectenonotus* .

Genus ***Pseudomera*** Holliday, 1942

Type species. *Amphion barrandei* Billings, 1865 from the Table Head Group, western Newfoundland (by original designation).

Pseudomera barrandei (Billings, 1865)

Plate 8, Figures 1-23, 25, 26.

1865 *Amphion barrandei* Billings, p. 288-299, fig. 277a, b.

1925 *Pliomerops barrandei* , Raymond, p. 153.

1942 *Pseudomera barrandei* , Holliday, p. 474, pl. 73, figs. 5-10.

1961 *Pseudomera barrandei* , Whittington, p. 918

1961 *Pseudomera* cf. *P. barrandei* , Whittington, p. 918-919, pl. 100,

figs. 11,12, 16, 17.

1970 *Pseudomera* cf. *P. barrandei* , Ross, p. 91, pl. 17, figs. 13,17.

1974 *Pseudomera barrandei* , Shaw, p. 34-35, pl. 9, figs. 5, 8, 11-14, 16-18.

Lectotype A cranidium (GSC 681b) from the Table Head Formation, designated by Whittington (1961).

Occurrences Table Head Formation, western Newfoundland; Oil Creek Formation, Oklahoma; Antelope Valley Limestone, Nevada; lower Sunblood Formation, Caribou Range (S-88, S-97, S-257, S-260). *Anomalorthis* Zone (Nevada and Utah), *Bathyurus mackenziensis* Zone (Canada).

Material 27 cranidia, 45 pygidia.

Discussion The presence of a medial depression in the anterior glabellar lobe of the exfoliated lectotype (Whittington 1961, pl. 100, fig. 8) seems to be a function of preservation. Shaw (1974, pl. 9, figs. 5, 8, 11-14, 16-18) assigned specimens from the Simpson Group of Oklahoma lacking a medial depression to *P. barrandei*, and his lead is followed herein. Comparable specimens from the Antelope Valley Limestone that are otherwise identical to the lectotype (Whittington1961, pl. 100, figs. 9, 11-17; Ross1970, pl. 17, figs. 13, 17)are also placed in this species. The Sunblood material is virtually indistinguishible from the specimens illustrated by Shaw (1974). The ontogeny of holaspid cranidia involves a posterior migration of the

palpebral lobe (see Pl. 8, Figs. 4, 11) which accounts for the more anteriorly located palpebral lobes of many of the small Sunblood specimens, and those illustrated by Shaw (1974), as compared to the large lectotype.

Family ENCRINURIDAE Angelin, 1854

Subfamily ENCRINURINAE Angelin, 1854

Genus ***Encrinuroides*** Reed 1931

Type species. *Cybele sexacostata* Salter, 1848 from Upper Orovician strata of Wales (by original designation).

Encrinuroides rarus (Walcott, 1877)

Plate 8, Figures 27-36.

1976 *Encrinuroides rarus* , Chatterton and Ludvigsen, p. 74, pl. 15, figs. 1 - 43 (see for complete synonymy).

1978 *Encrinuroides rarus* , Ludvigsen, pl. 2, fig. 22.

1979 *Encrinuroides rarus* , Ludvigsen, p. 45, pl. 21, figs. 42 - 48.

1987 *Encrinuroides rarus* , DeMott, in DeMott et al., p. 80, pl. 11, figs. 13-25.

Holotype Incomplete cranidium (UC 12322 - Field Museum of Natural History, Chicago), from the Platteville Group, Wisconsin.

Occurrences Platteville Group, Wisconsin; Esbataottine Formation, Flood

Creek and Sunblood Range; upper Sunblood Formation, Sunblood Range (Z-208). *Bathyurus granulosus* Zone, *B. ulu* Zone, *Ceraurinella nahanniensis* Zone, *Ceraurus gabrielsi* Zone.

Material Three partial cranidia, nine pygidia, five free cheeks.

Discussion A complete description and comparison of *Encrinuroides rarus* with other species were provided by Chatterton and Ludvigsen (1976). The cranidia from the Sunblood Formation illustrated herein have a slightly more tuberculate posterior portion of the glabella than do those from the Esbataottine Formation. In all other respects, the material from the Sunblood Formation compares closely with that from the Esbataottine Formation illustrated by Chatterton and Ludvigsen (1976, pl. 15, figs. 1-46).

Suborder PHACOPINA Struve, 1959

Superfamily DALMANITACEA Vogdes, 1890

Family PTERYGOMETOPIDAE Reed, 1905

Subfamily PTERYGOMETOPINAE Reed, 1905

Genus ***Calyptaulax*** Cooper, 1930

Type species. *Calyptaulax glabella* Cooper, 1930 from the Whitehead Formation, Quebec (by original designation).

Calyptaulax callirachis (Cooper, 1953)

Plate 8, Figures 37-39.

1953 *Calliops callirachis* Cooper, p. 39, pl. 18, figs. 1 - 6, 8 - 14.

1953 *Calliops loxorachis* Cooper, p. 37, pl. 16, figs. 7 - 11, 14.

1975a *Calyptaulax* sp. 1 Ludvigsen, pl. 4, figs. 27 - 29.

1976 *Calyptaulax callirachis* , Chatterton and Ludvigsen, p. 77 -80, pl. 16, figs. 1 - 35, pl. 22, figs. 2 - 4.

1978b *Calyptaulax callirachis* , Ludvigsen, pl. 1, fig. 1.

Holotype Cephalon and thorax (USNM 11653a), from the Edinburg Formation, Strasbourg Junction, Virginia.

Occurrences Edinburg Formation, Virginia; lower Esbataottine Formation, Sunblood Range; upper Sunblood Formation, Sunblood Range (Z-296). *Bathyurus granulosus* Zone, *Ceraurinella nahanniensis* Zone.

Material One cephalon.

Discussion This species was fully described by Chatterton and Ludvigsen (1976). The cephalon illustrated herein closely resembles those illustrated by Ludvigsen (1975a, pl. 4, figs. 27-29, 1978, pl. 1, fig. 1), and Chatterton and Ludvigsen (1976, pl. 16, figs. 1-35, pl. 22, figs. 2-4).

Order LICHIDA Moore, 1959

Family LICHIDAE Hawle and Corda, 1847

Subfamily TETRALICHINAE Phleger, 1936

Genus ***Amphilichas*** Raymond, 1905

Type species. *Platymetopus lineatus* Angelin, 1854 from the Boda Limestone of Sweden (by original designation).

Amphilichas sp.

Plate 8, Figure 41.

Occurrence Upper Sunblood Formation, Sunblood Mountain (Z-211). *Bathyurus granulosus* Zone.

Material Three free cheeks.

Discussion The lack of complete material precludes a close comparison with other species, but the free cheeks are similar to those of *A. conradi* Chatterton and Ludvigsen (1976, pl. 18, figs. 36-61) from the same interval of the study area.

Subfamily CERATARGINAE Tripp, 1957

Genus ***Hemiarges*** Gürich, 1901

Type species. *Lichas wesenbergensis* Schmidt, 1885 from the Rakvere Limestone of Estonia (subsequent designation by Reed, 1902).

Hemiarges sp.

Plate 8, Figure 40.

Occurrence Upper Sunblood Formation, Funeral Range (Y-30).

Material One pygidium.

Discussion The single pygidium has a slightly narrower axis than *H. turneri* Chatterton and Ludvigsen (1976, pl. 19, figs. 1-41) from the lower Esbataottine Formation in the study area.

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PLATES 1-8

All specimens were mounted on tooth picks, blackened with dilute India ink and then whitened with ammonium chloride prior to photography. The tooth picks were later blacked out of the photographs.

Stratigraphic and geographic locations of specimens are indicated by collection numbers (see appendices 1-6).

PLATE 1

Basilicus sp. Lower Sunblood Formation, Funeral Range.

1. Cranidium, dorsal view, Y-5, ROM 47565, x6.

2-4. Pygidium, dorsal, posterior and lateral views, Y-5, ROM 47566, x6.

Bumastoides cf. *B. lenzi* Chatterton and Ludvigsen. Sunblood Formation, Funeral Range and Sunblood Range.

5-7. Cranidium, lateral, oblique, and dorsal views, ROM 47567, Y-30, x6.

8. Pygidium, dorsal view, Y-30, ROM 47568, x6.

9. Pygidium, dorsal view, Z-208, ROM 47569, x5.

Isotelus cf. *I. harrisi* Raymond. Upper Sunblood Formation,Sunblood Range.

10. Free cheek, dorsal view, Z-296, ROM 47570, x6.

11. Free cheek, dorsal view, Z-296, ROM 47571, x5.

12. Hypostome, ventral view, Z-306, ROM 47572, x4.

13,14. Cranidium, dorsal and anterior views, Z-296, ROM 47573, x5.

Failleana sp. Upper Sunblood Formation, Sunblood Range.

15. Cranidium, dorsal view, Z-296, ROM 47574, x5.

16. Hypostome, ventral view, Z-284, ROM 47575, x5.

Illaenus sp. 1. Lower Sunblood Formation, Flood Creek.

17. Pygidium, ventral view, G-1825, ROM 47576, x5.

18. Cranidium, dorsal view, G-1825, ROM 47578, x5.

Illaenus sp. 2. Upper Sunblood Formation, Caribou Range.

20. Pygidium, dorsal view, S-369, ROM 47579, x5.

Bathyurus angustus Ross. Upper Sunblood Formation, Caribou Range (all from S-369).

21. Cranidium, dorsal view, ROM 47580, x5.

22. Cranidium, dorsal view, ROM 47581, x5.

23,24. Free cheek, dorsal and lateral views, ROM 47582, x5.

25. Free cheek, dorsal view, ROM 47583, x5.

26. Rostral plate, ventral view, ROM 47584, x6.

27. Rostral plate, dorsal view, ROM 47585, x6.

28. Hypostome, ventral view, ROM 47586, x4.5.

29. Pygidium, dorsal view, ROM 47587, x4.5.

30. Pygidium, dorsal view, ROM 47588, x4.5.

31. Pygidium, dorsal view, ROM 47589, x4.5.

32-34. Pygidium, dorsal, posterior, and lateral views, ROM 47590, x4.5.

35. Hyposome, ventral view, ROM 47591,x5.

36, 37. Cranidium, oblique, lateral, dorsal and anterior views,

39, 40. ROM 47592, x4.5.

38. Cranidium, dorsal view, ROM 47593, x4.5.

41. Cranidium, dorsal view, ROM 47594, x5.25.
42. Cranidium, dorsal view, ROM 47595, x4.5.
43. Free cheek, dorsal view, ROM 47596, x5.
44. Hyposome, lateral view, ROM 47597, x5.
45. Thoracic segment, dorsal view, ROM 47598, x4.
46. Hyposome, ventral view, ROM 47599, x5.
47. Pygidium, dorsal view, ROM 47600, x3.
48. Pygidium, dorsal view, ROM 47601, x3.


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PLATE 2

Bathyurus granulosus Ludvigsen. Upper Sunblood Formation, Sunblood Range and Funeral Range.

1-3. Cranidium, dorsal, lateral and anterior views, Z-306, ROM 47602, x5.25.

4. Hypostome, ventral view, Z-211, ROM 47603, x5.

5, 6. Free cheek, lateral and dorsal views, Z-211, ROM 47604, x5.

7, 8. Free cheek, dorsal and lateral views, Z-211, ROM 47605, x5.

9. Hypostome, dorsal view, Z-211, ROM 47606, x5.

10. Hypostome, ventral view, Z-211, ROM 47607, x5.

11. Hypostome, ventral view, Z-211, ROM 47608, x5.

12. Rostral plate, ventral view, Z-306, ROM 47609, x4.

13. Rostral plate, ventral view, Z-211, ROM 47610, x5.

14. Cranidium, dorsal view, Z-306, ROM 47611, x4.

15, 16. Cranidium, dorsal and lateral views, Z-211, ROM 47612, x5.

17-19. Cranidium, dorsal, anterior and lateral views, Z-284, ROM 47613, x5.

20. Hypostome, ventral view, ROM 47614, Z-306, x5.

21, 22. Pygidium, dorsal and lateral views, Z-306, ROM 47615, x5.25.

23, 24. Pygidium, dorsal and lateral views, Z-284, ROM 47616, x5.

25. Pygidium, dorsal view, Z-211, ROM 47617, x5.

26. Hypostome, ventral view, Y-154, ROM 47618, x5.

27-29. Cranidium, anterior, lateral and dorsal views, Z-284, ROM

47619, x5.

30, 31. Cranidium, dorsal and lateral views, Z-306, ROM 47620, x4.

32. Cranidium, dorsal view, Z-284, ROM 47621, x5.

33. Hypostome, ventral view, Z-306, ROM 47622, x4.

34. Pygidium, dorsal view, Z-306, ROM 47623, x4.

35. Pygidium, ventral view, Z-306, ROM 47624, x4.

36. Pygidium, ventral view, Z-306, ROM 47625, x4.

37. Pygidium, ventral view, Z-306, ROM 47626, x4.

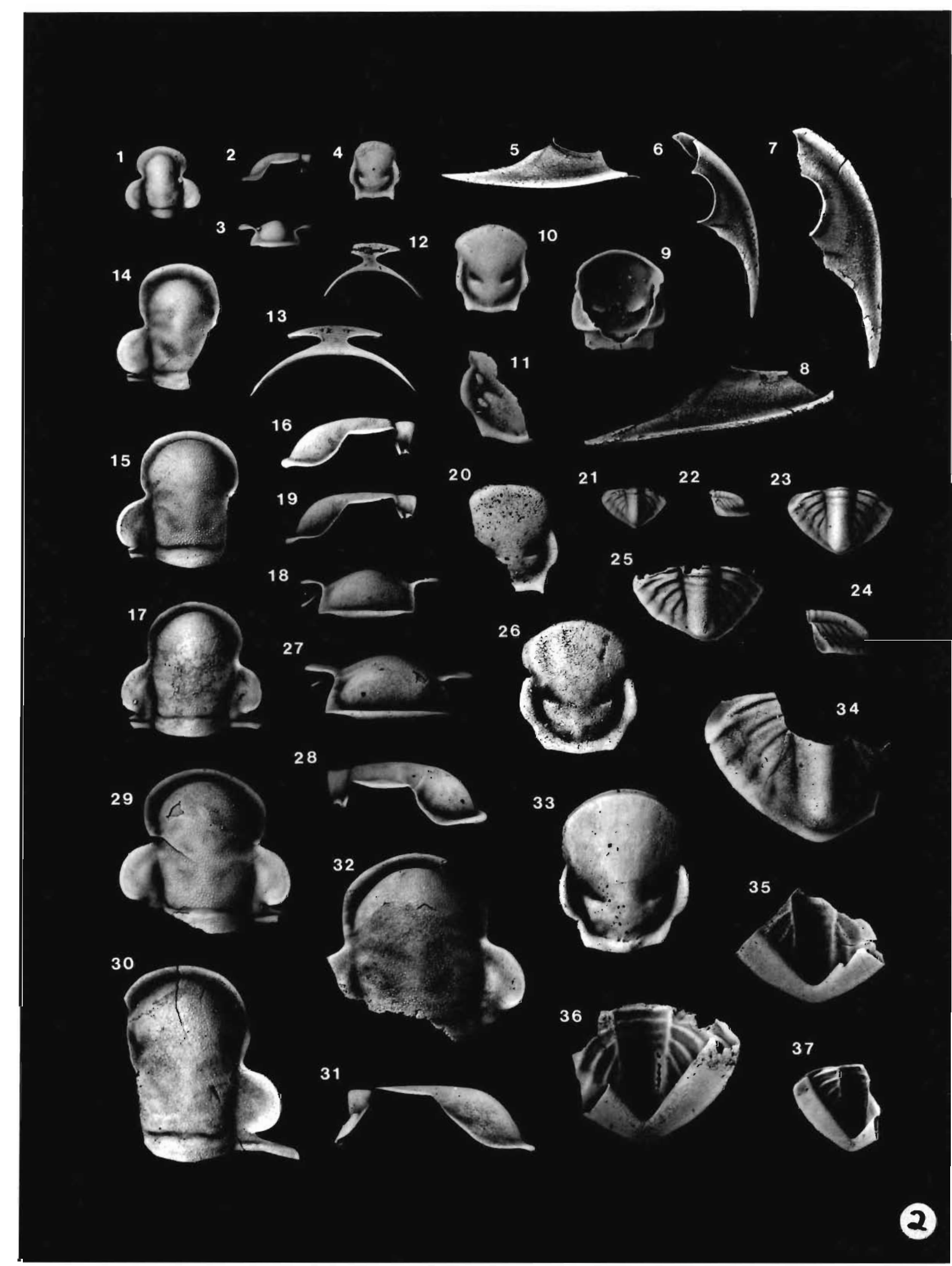
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PLATE 3

Bathyurus mackenziensis n. sp. Lower Sunblood Formation, Flood Creek and Caribou Range.

1, 2. Cranidium, dorsal and oblique views, S-88, ROM 47627, x5.

3. Rostral plate, ventral view, S-97, ROM 47628, x5.

4. Rostral plate, ventral view, S-257, ROM 47629, x5.25.

5, 6. Hypostome, oblique and ventral views, S-88, ROM 47630, x6.

7, 8. Pygidium, lateral and dorsal views, S-21, ROM 47631, x5.25.

9, 10. Pygidium, dorsal and lateral views, S-88, ROM 47632, x4.25.

11. Hypostome, ventral view, S-88, ROM 47633, x5.

12, 14. Hypostome, lateral and ventral views, S-97, ROM 47634, x3.75.

13. Hypostome, posterior view, S-97, ROM 47635, x3.75.

15. Cranidium, ventral view, S-88, ROM 47636, x5.

16. Cranidium, dorsal view, S-290, ROM 47637, x5.

17. Cranidium, dorsal view, S-88, ROM 47637, x5.

18, 19. Cranidium, dorsal and oblique views, S-290, ROM 47638, x5.

20. Cranidium, ventral view, S-257, ROM 47639, x5.25.

21. Cranidium, dorsal view, S-290, ROM 47640, x5.

22, 23. Cranidium, dorsal and oblique views, S-88, ROM 47641, x5.

24. Free cheek, dorsal view, S-290, ROM 47642, x5.

25. Free cheek, dorsal view, S-88, ROM 47643, x5.

26. Pygidium, dorsal view, S-257, ROM 47644, x5.25.

27. Pygidium, dorsal view, S-21, ROM 47645, x6.

28. Pygidium, dorsal view, S-88, ROM 47646, x9.

29. Pygidium, dorsal view, S-88, ROM 47647, x5.

30. Pygidium, ventral view, S-97, ROM 47648, x5.

31, 32. Cranidium, anterior and dorsal views, S-88, ROM 47649, x6.

33-35. Cranidium, dorsal, lateral and anterior views, S-88, ROM 47650, (HOLOTYPE) x4.

36, 37. Free cheek, lateral and dorsal views, S-290, ROM 47651, x5.

38, 39. Free cheek, dorsal and latera views, S-257, ROM 47652, x5.25.

40. Pygidium, ventral view, S-88, ROM 47653, x5.

41. Pygidium, ventral view, S-257, ROM 47654, x5.25.

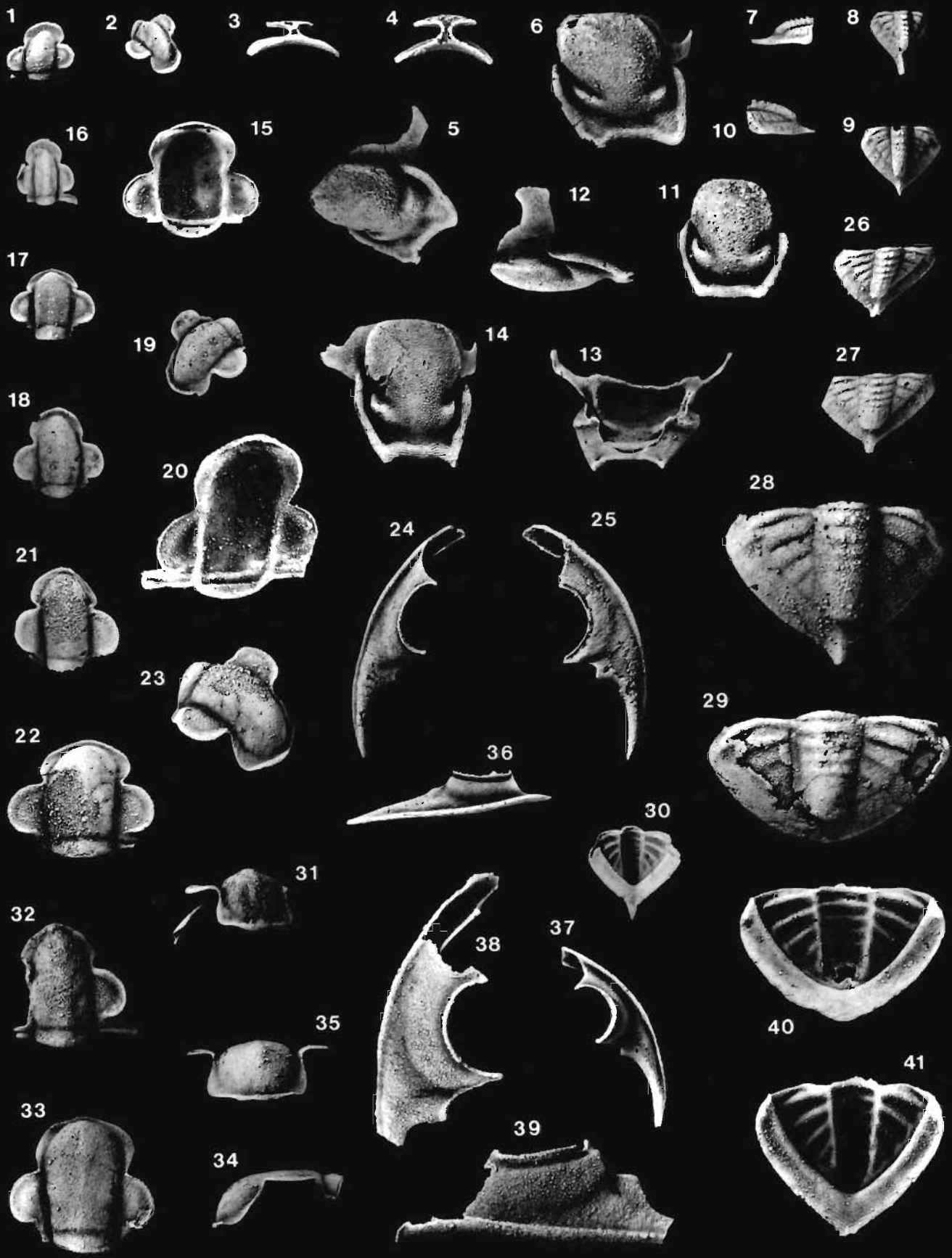
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PLATE 4

Bathyurus sunbloodensis n. sp. Lower Sunblood Formation, Sunblood Range.

1, 2. Cranidium, dorsal and lateral views, P-55, ROM 47655, x5.25.

3. Cranidium, dorsal view, P-55, ROM 47656, x5.25.

4. Cranidium, dorsal view, P-55, ROM 47657, x5.25.

5. Hypostome, ventral view, P-10, ROM 47658, x5.25.

6. Hypostome, ventral view, P-30, ROM 47659, x4.

7. Rostral plate, ventral view, P-55, ROM 47660, x7.

8. Rostral plate, ventral view, P-55, ROM 47661, x5.

9, 10. Free cheek, lateral and dorsal views, P-10, ROM 47662, x3.75.

11, 12. Free cheek, dorsal and lateral views, P-10, ROM 47663, x3.75 and x5.

13. Pygidium, dorsal view, P-10, ROM 47664, x6.

14, 15. Pygidium, dorsal and lateral views, P-55, ROM 47665, x4.5.

16. Pygidium, dorsal view, P-55, ROM 47666, x4.5.

17. Pygidium, dorsal view, P-10, ROM 47667, x5.25.

18, 19. Pygidium, dorsal and posterior views, P-10, ROM 47668, x3.75.

20, 21. Pygidium, dorsal and lateral views, P-30, ROM 47669, x5.

22. Pygidium, dorsal view, P-55, ROM 47670, x4.

23. Cranidium, ventral view, P-55, ROM 47671, x4.

24. Free cheek, dorsal view, P-10, ROM 47672, x6.

25. Hypostome, ventral view, P-55, ROM 47673, x5.

26-28. Cranidium, anterior, dorsal and lateral views, P-10, ROM

47674, x5.25.

29. Cranidium, dorsal view, P-30, ROM 47675 x5.

30. Cranidium, dorsal view, P-55, ROM 47676, x5.25.

31. Cranidium, ventral view, P-30, ROM 47677, x4.

32-34. Cranidium, lateral, dorsal and anterior views, P-30, ROM 47678, (HOLOTYPE) x4.

35. Pygidium, ventral view, P-55, ROM 47679, x4.

36, 37. Pygidium, lateral and dorsal views, P-30, ROM 47680, x4.

38. Pygidium, dorsal view, P-30, ROM 47681, x4.

39. Pygidium, ventral view, P-30, ROM 47682, x4.

40-42. Cephalon, anterior, dorsal and lateral views, P-55, ROM 47683, x4.

43. Thoracic segment, dorsal view, P-55, ROM 47684, x5.

44. Thoracic segment, dorsal view, P-10, ROM 47685, x4.

45. Pygidium, dorsal view, P-55, ROM 47686, x4.

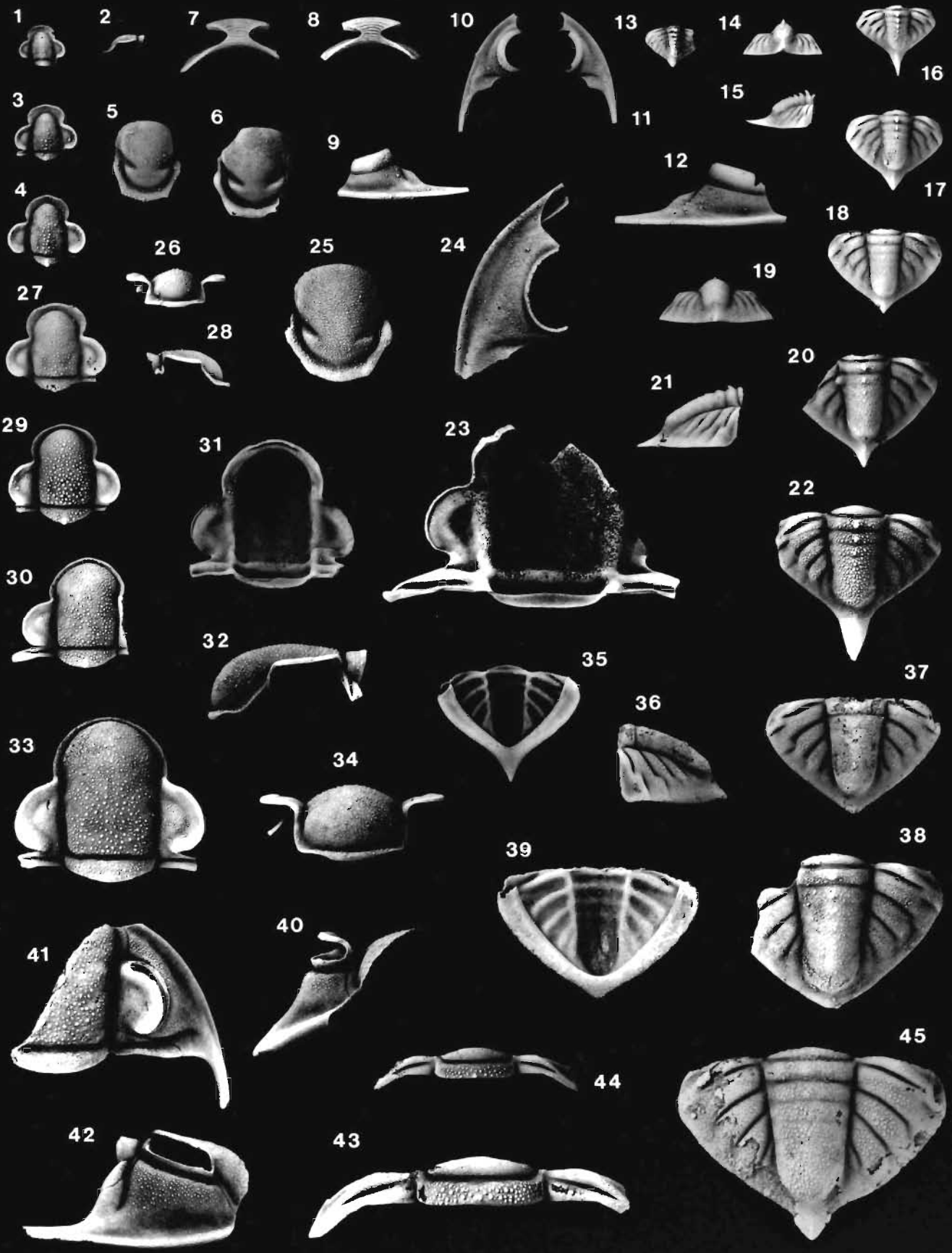
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PLATE 5

Bathyurus margareti n. sp. Lower Sunblood Formation, Sunblood Range and Mary Range.

1-3. Cranidium, dorsal, anterior and lateral views, B-360, ROM 47687, (HOLOTYPE) x5.

4. Cranidium dorsal view, B-360, ROM 47688, x5.

5. Cranidium, ventral view, B-360, ROM 47689, x5.

6. Rostral plate, ventral view, B-360, ROM 47690, x5.

7, 8. Free cheek, lateral and dorsal views, B-360, ROM 47691, x5.

9. Pygidium, dorsal view, P-115, ROM 47692, x4.5.

10. Pygidium, dorsal view, P-105, ROM 47693, x4.5.

11-13. Pygidium, lateral, posterior and dorsal views, B-360, ROM 47694, x5.

14. Pygidium, dorsal view, P-115, ROM 47695, x4.

15. Pygidium, dorsal view, B-360, ROM 47696, x5.

16. Pygidium, ventral view, P-360, ROM 47697, x5.

17. Pygidium, dorsal view, B-360, ROM 47698, x5.

18-20. Pygidium, lateral, dorsal and ventral views, P-105, ROM 47699, x4, and x3.

21-23, 29. Pygidium, dorsal, lateral, posterior and ventral views, B-360, ROM 47700, x5 and x4.

24. Hypostome, ventral view, B-360, ROM 47701, x5.

25. Hypostome, ventral view, P-115, ROM 47702, x4.5.

26. Hypostome, ventral view, P-115, ROM 47703, x5.

27, 28. Hypostome, ventral and lateral vies, B-360, ROM 47704, x5.

29. Pygidium, ventral view, B-360, ROM 47705, x5.

Bathyurus acanthopyga n. sp. Sunblood Formation, Funeral Range (all from Y-5).

30-33. Oblique, dorsal, anterior and lateral views, ROM 47706, (HOLOTYPE) x5.

34. Free cheek, lateral view, ROM 47707, x6.

35. Pygidium, ventral view, ROM 47708, x5.

36. Hypostome, ventral view, ROM 47709, x3.

37. Hypostome, ventral view, ROM 47710, x5.

38. Rostral plate, ROM 47711, x5.

39. Thoracic segment, ROM 47712, x5.

40-42. Pygidium, dorsal, lateral and posterior views, ROM 47713, x5.

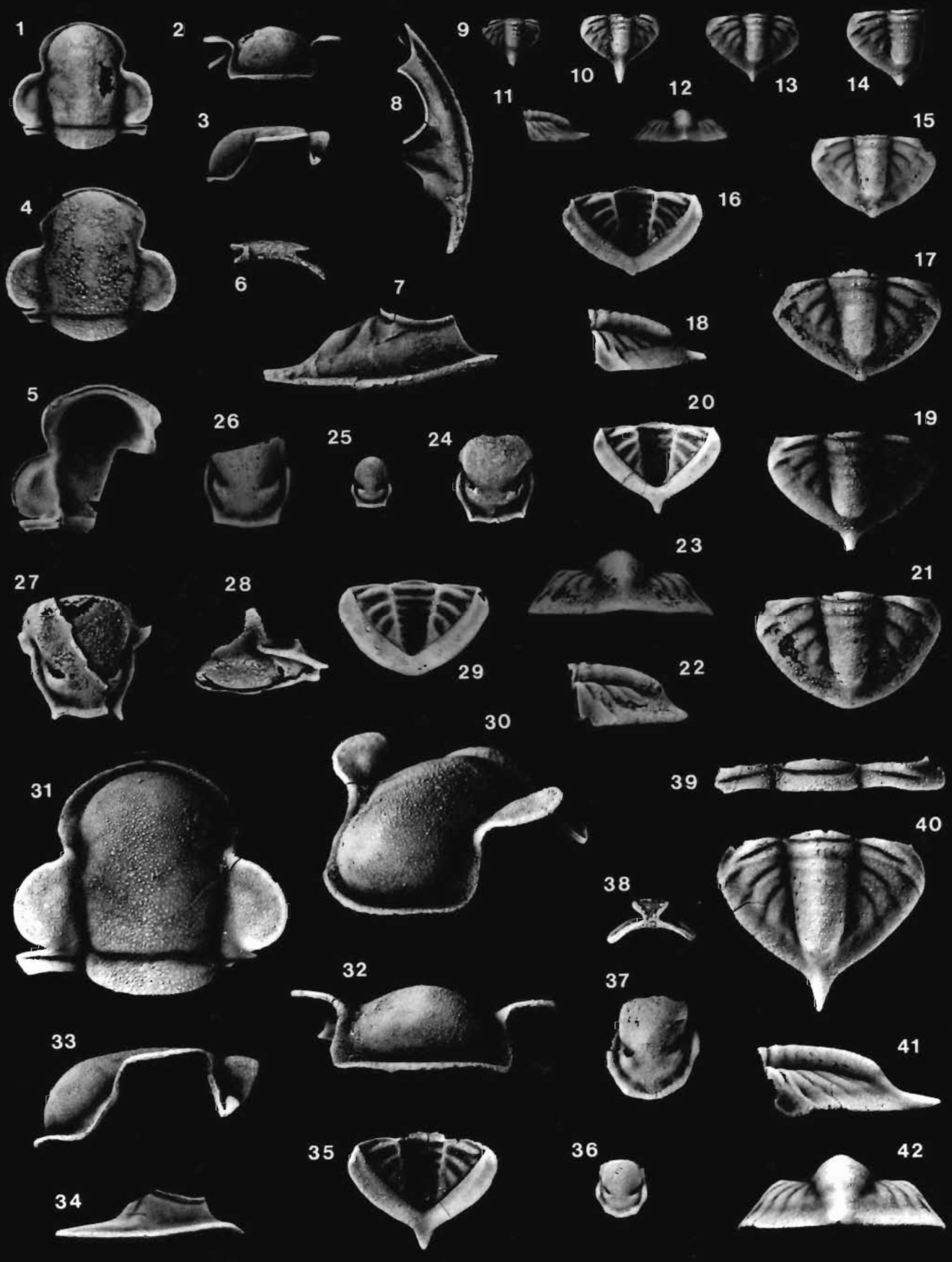
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PLATE 6

Bathyurus acanthopyga n. sp. Sunblood Formation, Funeral Range (all from Y-5).

1, 3. Cranidium, dorsal and oblique views, ROM 47714, x6.

2, 4, 5. Cranidium, dorsal, anterior and lateral views, ROM 47715, x6.

6. Free cheek, dorsal view, ROM 47716, x4.5.

7. Free cheek, dorsal view, ROM 47717, x5.

8, 9. Pygidium, dorsal and lateral views, ROM 47718, x6.

10. Pygidium, ventral view, ROM 47719, x5.

11. Pygidium, dorsal view, ROM 47720, x5.

12. Pygidium, dorsal view, ROM 47721, x5.

13,14. Pygidium, dorsal and lateral views, ROM 47722, x5.

15. Cranidium, ventral view, ROM 47723, x5.

16,17. Cranidium, dorsal and anterior views, ROM 47724, x5.

18. Cranidium, dorsal view, ROM 47725, x5.

19, 20. Cranidium, dorsal and lateral views, ROM 47726, x5.

21. Pygidium, ventral view, ROM 47727, x5.

?*Bathyurus* sp. Lower Sunblood Formation, Flood Creek.

22. Cranidium, dorsal view, G-1425, ROM 47728, x4.

23. Pygidium, dorsal view, G-1425, ROM 47729, x4.

24. Free cheek, lateral view, G-1425, ROM 47730, x4.

25. Pygidium, dorsal view, G-1425, ROM 47731, x4.

Ludvigsenella ellipsepyga n. gen, n. sp. Lower Sunblood Formation, Caribou Range and Sunblood Range.

26. Cranidium, dorsal view, BVF, ROM 47732, x5.

27, 28. Cranidium, dorsal and oblique views, BVF, ROM 47733, (HOLOTYPE) x4.

29, 30. Hypostome, lateral and ventral views, BVF, ROM 47734, x4.

31. Cranidium, dorsal view, BVF, ROM 47735, x5.

32, 33. Cranidium, oblique and dorsal views, S-97, ROM 47736, x3.75.

34. Pygidium, dorsal view, S-97, ROM 47737, x5.

35, 36. Pygidium, lateral and dorsal views, S-97, ROM 47738, x5.

37. Pygidium, ventral view, S-97, ROM 47739, x5.

38. Pygidium, ventral view, BVF, ROM 47740, x5.


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PLATE 7

Ludvigsenella ellipsepyga n. gen, n. sp. Lower Sunblood Formation, Caribou Range and Sunblood Range.

1. Cranidium, dorsal view, BVF, ROM 47741, x5.
2, 3. Cranidium, anterior and dorsal views, BVF, ROM 47742, x5.
4-6. Cranidium, dorsal, lateral and anterior views, BVF, ROM 47743, x5.
7, 8. Free cheek, lateral and dorsal views, BVF, ROM 47744, x5.
9. Free cheek, lateral view, BVF, ROM 47745, x5.
10, 11. Free cheek, dorsal and lateral views, BVF, ROM 47746, x5.
12. Thoracic segment, dorsal view, BVF, ROM 47747, x5.
13. Thoracic segment, ventral view, BVF, ROM 47748, x5.
14. Hypostome, ventral view, BVF, ROM 47749, x5.
15. Cranidium, ventral view, BVF, ROM 47750, x5.

Phorocephala cf. *P. pinguimitra* (Chatterton and Ludvigsen). Upper Sunblood Formation, Sunblood Range.

16. Pygidium, dorsal view, Z-208, ROM 47751, x7.5.
17. Free cheek, dorsal view, Z-208, ROM 47752, x4.5.

Ceraurinella nahanniensis Chatterton and Ludvigsen. Upper Sunblood Formation, Sunblood Range.

18-20. Cranidium, lateral, dorsal and anterior views, Z-211, ROM

47753, x7.5.

Ceraurinella sp. Sunblood Formation, Funeral Range.

21. Cranidium, dorsal view, Y-30, ROM 47754, x8.

Xystocrania perforator (Billings). Lower Sunblood Formation, Flood Creek and Caribou Range.

22. Cranidium, dorsal view, S-97, ROM 47755, x5.

23. Hypostome, ventral view, S-290, ROM 47756, x5.

24. Cranidium, dorsal view, S-290, ROM 47757, x5.

25, 26. Cranidium, dorsal and lateral views, S-97, ROM 47758, x5.

27. Free cheek, lateral view, S-290, ROM 47759, x5.

28. Pygidium, ventral view, S-290, ROM 47760, x5.

29, 30. Pygidium, dorsal and posterior views, S-290, ROM 47761, x5.

31-33. Cranidium, oblique, anterior and dorsal views, S-290, ROM 47762, x5.

34. Pygidium, ventral view, S-290, ROM 47763, x5.

35. Pygidium, dorsal view, S-290, ROM 47764, x5.

36. Pygidium, dorsal view, S-97, ROM 47765, x5.

Cydonocephalus cf. *C torulus* Whittington. Lower Sunblood Formation, Sunblood Range and Caribou Range.

37-39. Pygidium, dorsal, posterior and lateral views, S-88, ROM 47766, x5.

40. Pygidium, dorsal view, S-88, ROM 47767, x5.

41. Pygidium, dorsal view, S-88, ROM 47768, x5.
42. Pygidium, ventral view, S-88, ROM 47769, x5.
43. Cranidium, dorsal view, S-88, ROM 47770, x7.
44. Cranidium, dorsal view, S-88, ROM 47771, x8.
45. Cranidium, dorsal view, S-88, ROM 47772, x6.
46. Cranidium, dorsal view, S-88, ROM 47773, x4.
47. Cranidium, dorsal view, S-88, ROM 47774, x4.


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PLATE 8

Pseudomera barrandei (Billings). Lower Sunblood Formation, Caribou Range.

1. Cranidium, dorsal view, S-257, ROM 47775, x5.25.
2, 3. Cranidium, dorsal and oblique views, S-257, ROM 47776, x5.25.
4, 5. Cranidium, dorsal and lateral views, S-257, ROM 47777, x5.25.
6, 7. Hypostome, ventral and lateral views, S-257, ROM 47778, x5.25.
8. Hypostome, ventral view, S-257, ROM 47779, x5.25.
9, 10. Hypostome, lateral and ventral views, S-257, ROM 47780, x5.25.
11. Cranidium, dorsal view, S-257, ROM 47781, x5.25.
12. Pygidium, dorsal view, S-257, ROM 47782, x5.25.
13-15. Pygidium, lateral, posterior and dorsal views, S-257, ROM 47783, x5.25.
16. Pygidium, dorsal view, S-257, ROM 47784, x5.25.
17. Pygidium, dorsal view, S-257, ROM 47785, x5.25.
18. Pygidium, ventral view, S-257, ROM 47786, x5.25.
19, 20. Pygidium, lateral and dorsal views, S-257, ROM 47787, x5.25.
21, 22. Pygidium, dorsal and lateral views, S-88, ROM 47788, x5.
23. Pygidium, ventral view, S-257, ROM 47789, x5.25.
25. Free cheek, lateral view, S-88, ROM 47790, x5.
26. Free cheek, lateral view, S-88, ROM 47791, x5.

Ectenonotus sp. Lower Sunblood Formation, Flood Creek and Caribou Range.

24. Pygidium, dorsal view, S-97, ROM 47792, x3.75.

Encrinuroides rarus (Walcott). Upper Sunblood Formation, Sunblood Range.

27-30. Cranidium, lateral, anterior, oblique and dorsal views, Z-208, ROM 47793, x7.5.

31. Pygidium, dorsal view, Z-208, ROM 47794, x6.

32. Free cheek, lateral view, Z-208, ROM 47795, x6.

33-35. Pygidium, lateral, posterior and dorsal views, ROM 47796, x6.

36. Free cheek, lateral view, Z-208, ROM 47797, x6.

Calyptaulax callirachis (Cooper). Upper Sunblood Formation, Sunblood Range.

37-39. Cephalon, dorsal, lateral and anterior views, Z-296, ROM 47798, x6.25.

Hemiarges sp. Sunblood Formation, Funeral Range.

40. Pygidium, dorsal view, Y-30, ROM 47799, x6.

Amphilichas sp. Upper Sunblood Formation, Sunblood Range.

41. Free cheek, dorsal view, Z-208, ROM 47800, x6.


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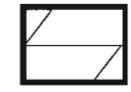
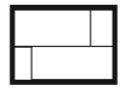
APPENDICES 1-6

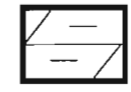
For each measured section, a listing of the number of cranidia/cephala, pygidia, and individuals of species identified in each collection is followed by a lithologic log. The number of individuals may have been arrived at by counting the number of hypostoma or same-side free cheeks. Note that collection numbers give the locations, in metres (in feet for sections G, P, and B), of the collections above the base of the section.

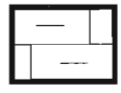
GUIDE TO LITHOLOGIC SYMBOLS USED IN APPENDICES

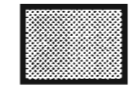

COVERED INTERVAL


DOLOSTONE


LIMESTONE


SILTY AND SANDY DOLOSTONE


SILTY LIMESTONE


SANDSTONE

FEN = Fenestral fabric

DES = Desiccation polygons

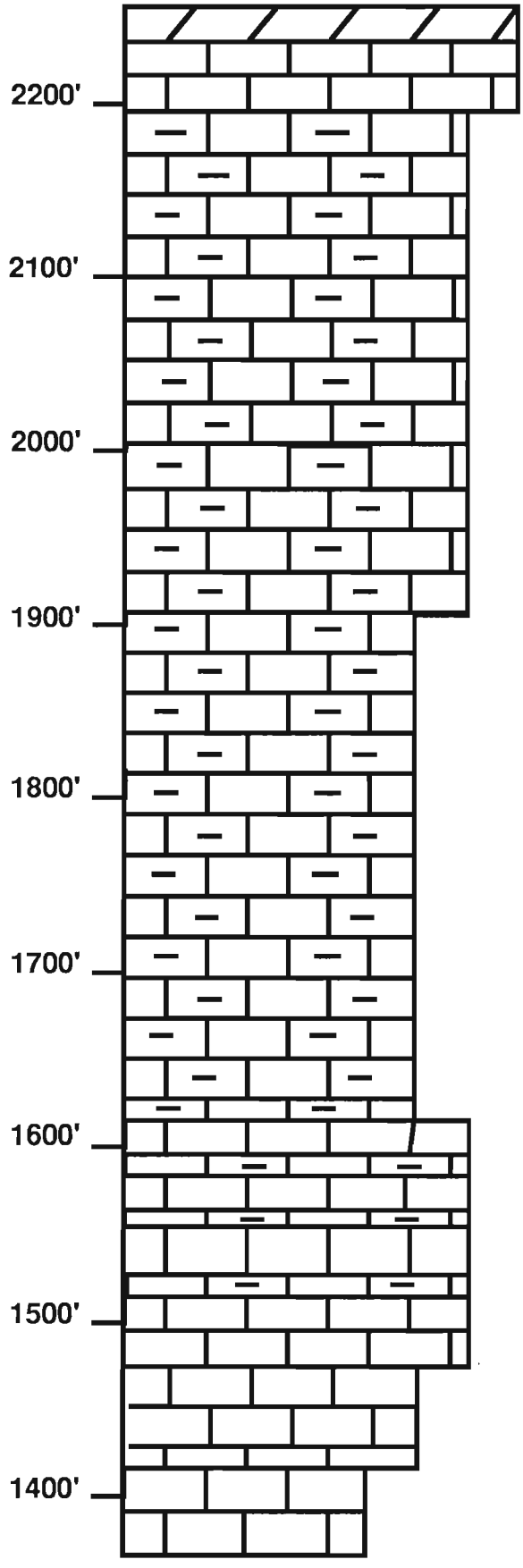
APPENDIX 1

Section G

The standard reference section of the Sunblood Formation was measured just east of Flood Creek (62° 11', 126° 42'). The interval presented here is just a portion of that measured by Ludvigsen (see Fig. 2).

G-1425	Cranidia	Pygidia	Individuals
?*Bathyurus* sp.	(Numerous deformed fragments)		
G-1745			
Xystocrania perforator	2	1	2
Bathyurus mackenziensis			2
Ectenonotus sp.		1	1
G-1760			
Bathyurus mackenziensis		4	4
G-1825			
Illaenus sp.	1	27	27
Bathyurus mackenziensis	3		3
Pseudomera barrandei		2	2
G-1850			
Bathyurus mackenziensis	3		5

G-2170			
?*Bathyurus mackenziensis*	2	6	6

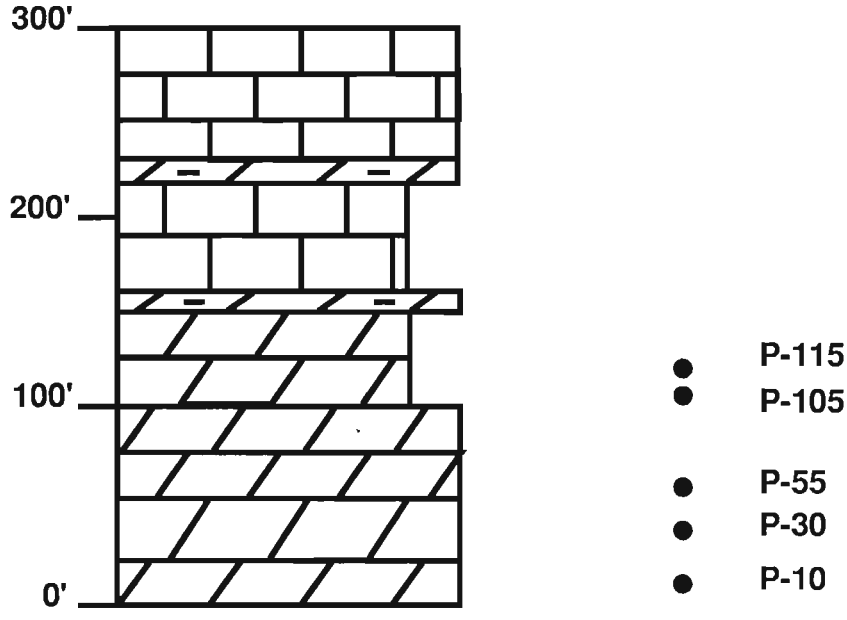

2200'
2100'
2000'
1900'
1800'
1700'
1600'
1500'
1400'
G-2170
G-1850
G-1825
G-1760
G-1745
G-1425

APPENDIX 2

Section P

This section was measured in the Sunblood Range (61° 43' 30", 125° 56'). The interval presented here is just a portion of that measured by Ludvigsen (see Fig. 2).

P-10	Cranidia	Pygidia	Individuals
Bathyurus sunbloodensis	19	44	44
P-30			
Bathyurus sunbloodensis	60	101	101
P-55			
Bathyurus sunbloodensis	41	40	41
Cydonocepahalus cf. *C. torulus*		1	1
P-105			
Bathyurus margareti	3	8	8
P-115			
Bathyurus margareti	11	44	44


300'
200'
100'
0'
P-115
P-105
P-55
P-30
P-10

APPENDIX 3

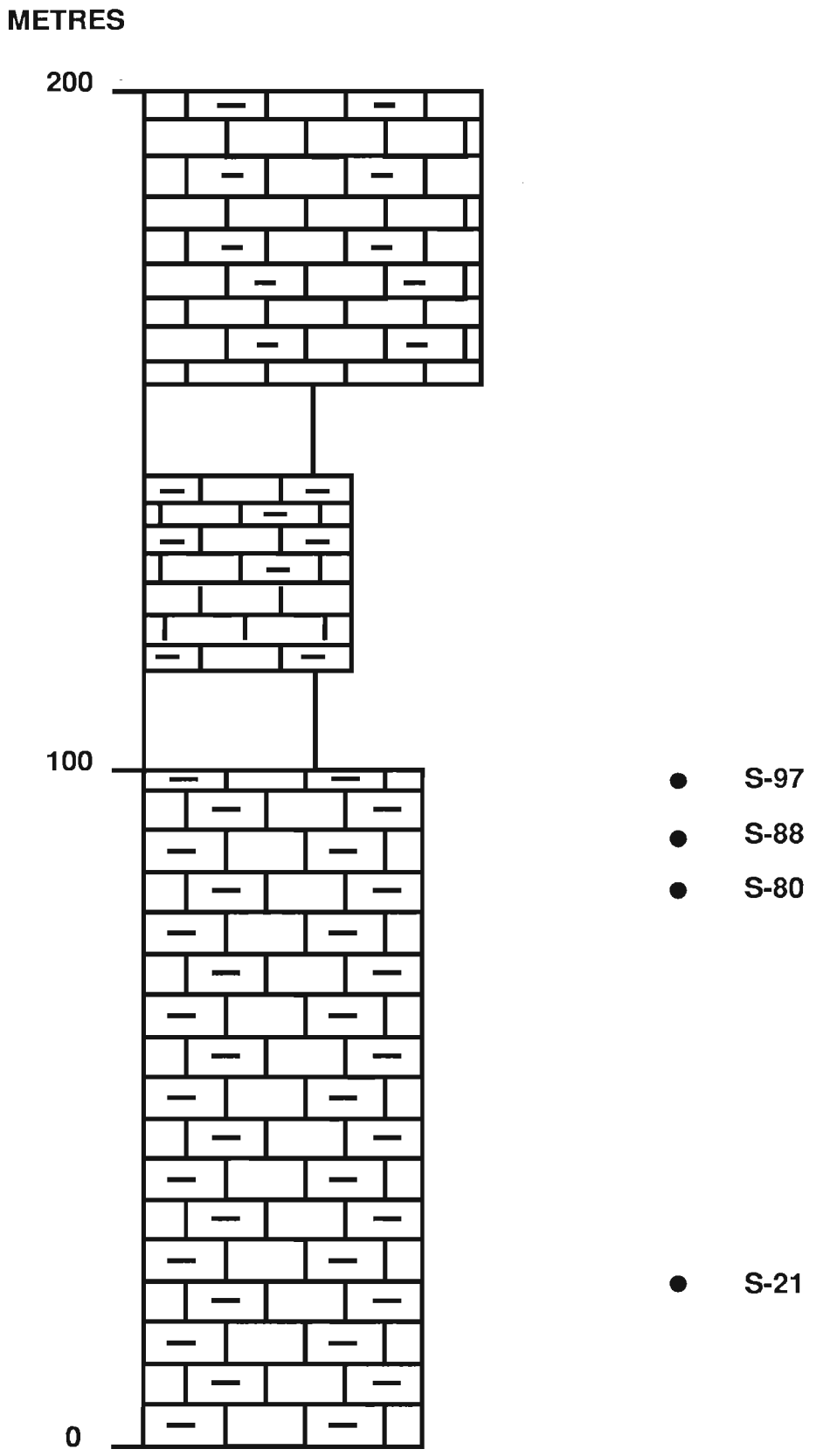
Section S

This section was measured in the Caribou Range (61° 12', 125° 47'). The interval presented here is just a portion of that measured by Ludvigsen (see Fig. 2).

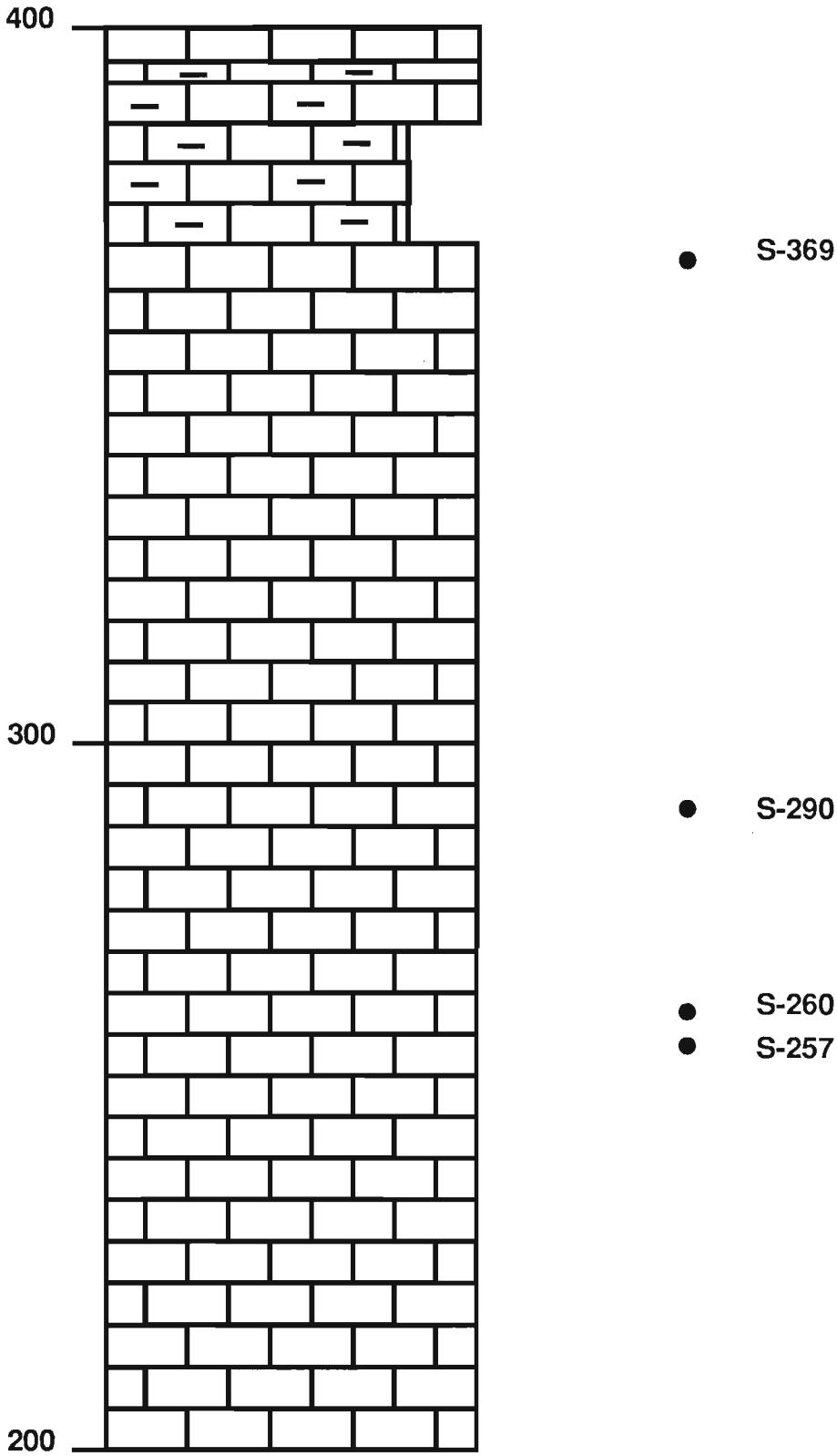
S-21	Cranidia	Pygidia	Individuals
Bathyurus mackenziensis	21	32	32
S-80			
Bathyurus mackenziensis	10	3	10
Xystocrania perforator	1	4	4
Ludvigsenella ellipsepyga	1		3
Cydonocephalus cf. *C. torulus*		1	1
S-88			
Bathyurus mackenziensis	42	54	54
Pseudomera barrandei	19	27	27
Cydonocephalus cf. *C. torulus*	9	13	13
Xystocrania perforator	8	11	11
Ludvigsenella ellipsepyga	9	4	9

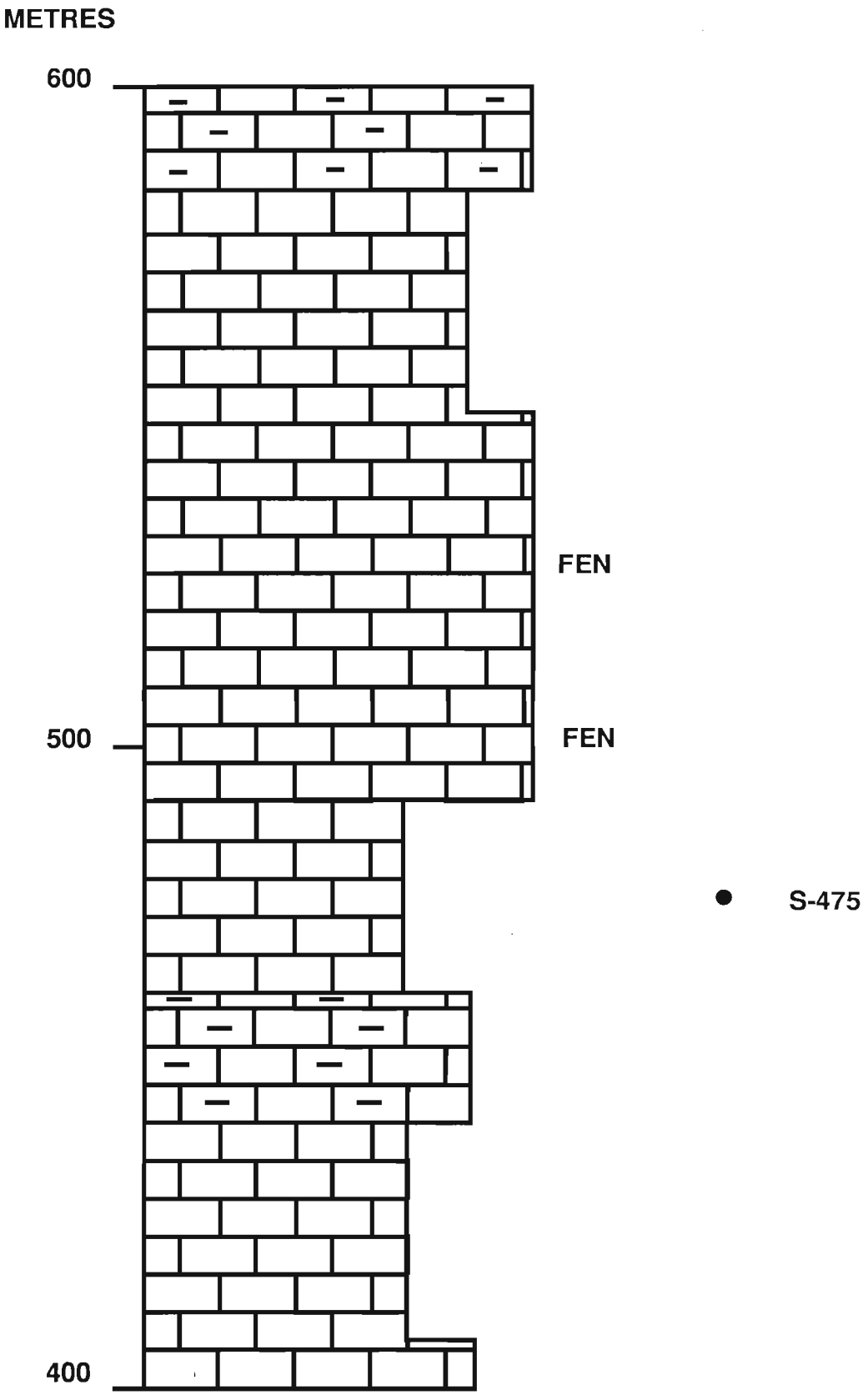
S-97	Cranidia	Pygidia	Individuals
Ludvigsenella ellipsepyga	15	21	21
Bathyurus mackenziensis	16	16	16
Xystocrania perforator	11	10	11
Pseudomera barrandei	1	2	2
Cydonocephalus cf. *C. torulus*	2	2	2
Ectenonotus sp.	1	2	2
S-257			
Bathyurus mackenziensis	5	8	8
Pseudomera barrandei	2	6	6
S-260			
Bathyurus mackenziensis	14	22	22
Pseudomera barrandei	8	5	8
S-290			
Xystocrania perforator	110	84	110
Bathyurus mackenziensis	96	91	96
Ludvigsenella ellipsepyga	6	6	6
Cydonocephalus cf. *C. torulus*		2	2
S-369			
Bathyurus angustus	57	242	242

Illaenus sp.	5	5
S-475		
Pseudomera barrandei	4	4
Bathyurus angustus	2	2


METRES
200
100
0
S-97
S-88
S-80
S-21

METRES




METRES
600
500
400
FEN
FEN
S-475

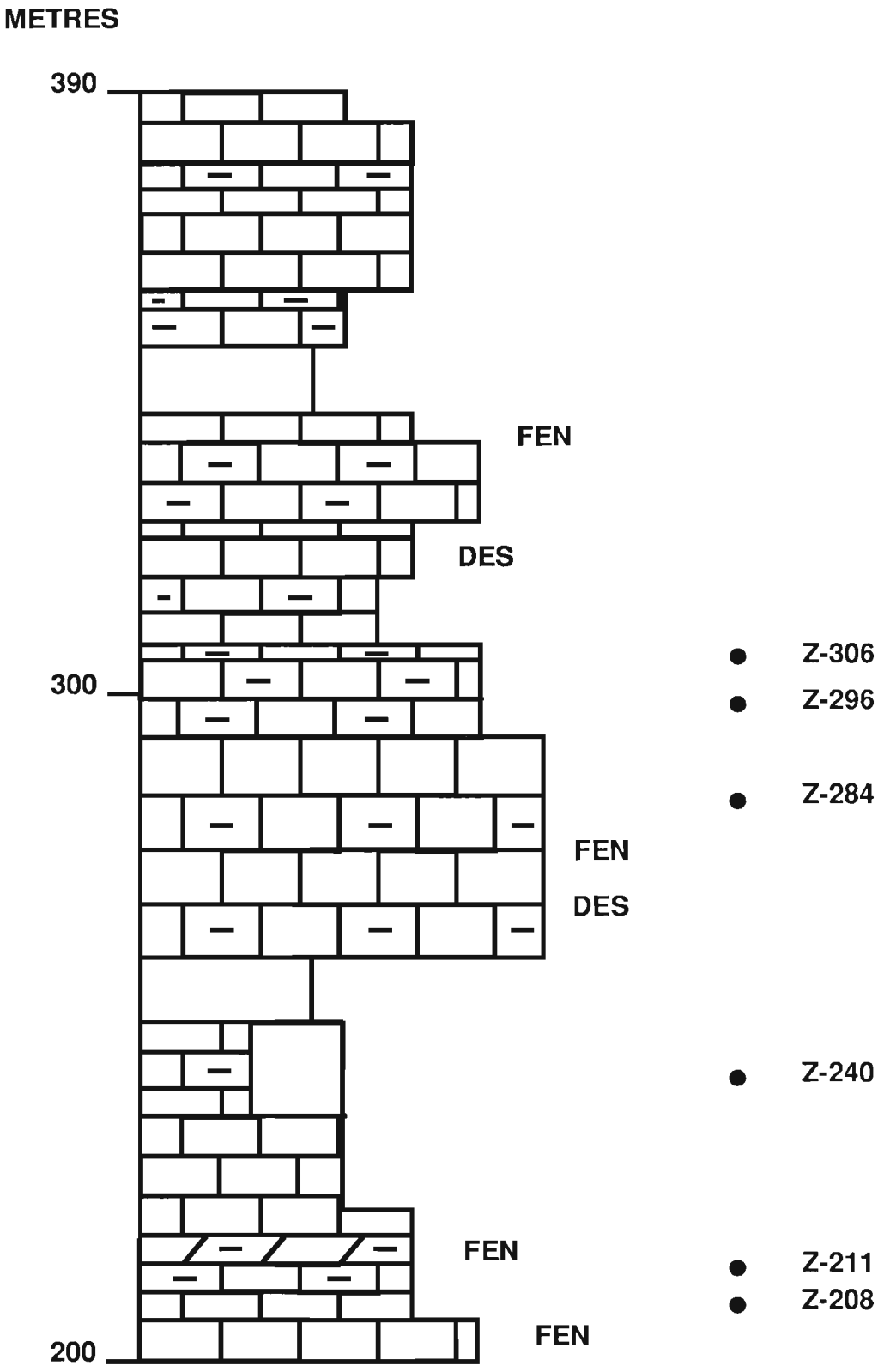
APPENDIX 4

Section Z

This section was measured in the Sunblood Range on a ridge immediately above Virginia Falls (61° 31', 125° 44'). A single collection was made from the base of Virginia Falls (BVF). The interval presented here is just a portion of that measured by Ludvigsen (see Fig. 2).

Z-208	Cranidia	Pygidia	Individuals
Encrinuroides rarus	3	9	9
Bumastoides cf. *B. lenzi*		9	9
Phorocephala cf. *P. pinguimitra*		1	6
Z-211			
Bathyurus granulosus	7	14	21
Amphilichas sp.	1		3
Isotelus cf. *I. harrisi*	1		1
Ceraurinella nahanniensis	1		1
Z-240			
Bathyurus granulosus	1	1	1
Isotelus cf.*I. harrisi*			3
Illaenid sp.			1
Z-284			

	Cranidia	Pygidia	Individuals
Bathyurus granulosus		8	12	19
Illaenid sp.				1
Z-296				
Isotelus cf. *I. harrisi*		4	2	4
Failleana sp.		1		1
Calyptaulax callirachis		1		1
Z-306				
Bathyurus granulosus		25	37	100
Isotelus cf. *I. harrisi*		1		8
Acanthoparypha evitti		2	1	2
BVF				
Ludvigsenella ellipsepyga		28	19	28
Bathyurus mackenziensis		10	2	10

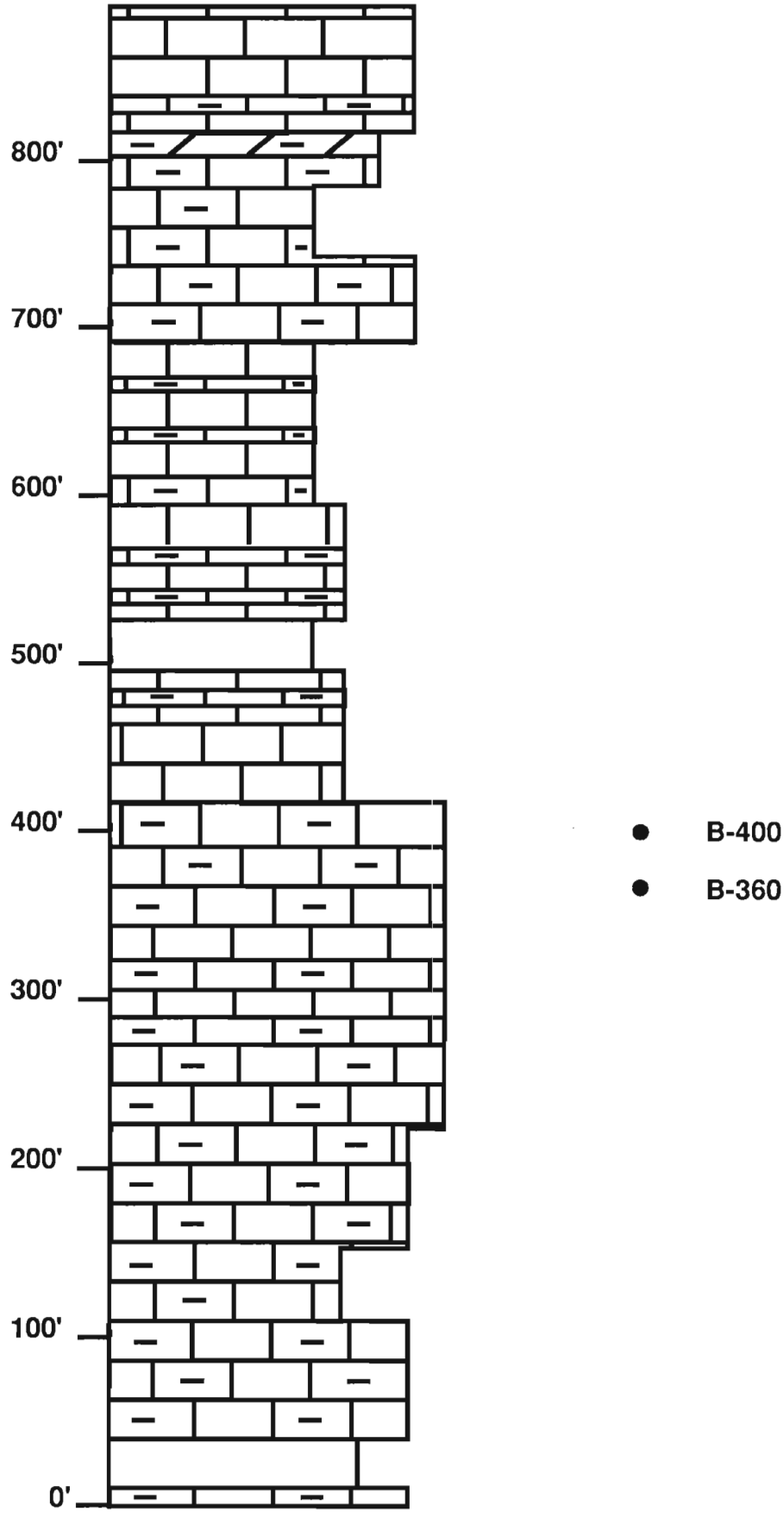

METRES
390
300
200
FEN
DES
FEN
DES
FEN
FEN
Z-306
Z-296
Z-284
Z-240
Z-211
Z-208

APPENDIX 5

Section B

This section was measured in the Mary Range (61° 19', 125° 23'). The interval presented here is just a portion of that measured by Ludvigsen (see Fig. 2).

B-360	Cranidia	Pygidia	Individuals
Bathyurus margareti	12	47	47
B-400			
Bathyurus margareti	16	11	16

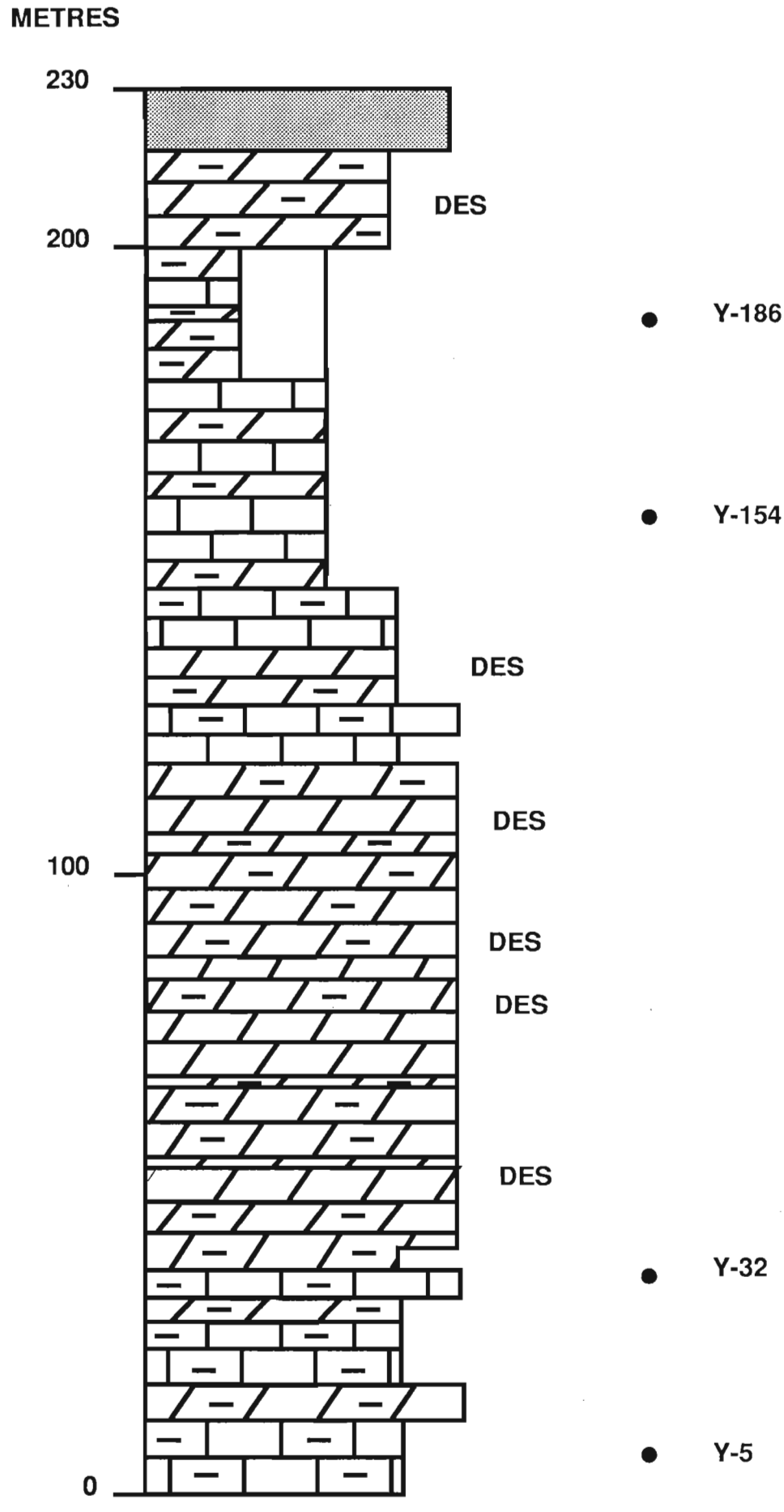

800'
700'
600'
500'
400'
300'
200'
100'
0'
B-400
B-360

APPENDIX 6

Section Y

This section was measured in the Funeral Range, immediately south of the South Nahanni River (61° 28', 125° 04').

Y-5	Cranidia	Pygidia	Individuals
Bathyurus acanthopyga	76	176	176
Basilicus sp.	1	1	1
Y-30			
Bumastoides cf. *B. lenzi*	4	5	5
Cerurinella sp.	1	2	3
Y-32			
Bathyurus acanthopyga	fragments		
Y-154			
Bathyurus granulosus	7	12	12
Y-186			
Bathyurus granulosus	3	3	3


METRES
230
200
100
0
DES
DES
DES
DES
DES
DES
Y-186
Y-154
Y-32
Y-5